

3 May 2013

MEMORANDUM

To: Ellen Belk, EPA Region 6
Cc: Susan Wolf, RTI International
From: Uarporn Nopmongkol, Greg Yarwood
Subject: 2018 Base Case CAMx Simulation, Texas Regional Haze Evaluation
[Contract EP-W-011-029]

ENVIRON is assisting EPA by evaluating regional haze impacts of selected sources in Texas. The analysis builds upon modeling of 2002 and 2018 conducted previously for CENRAP by ENVIRON. The CENRAP database was enhanced to include a 12 km grid over Texas and nearby Class I areas, and updated to use with the latest version of the Comprehensive Air Quality Model with extensions (CAMx; ENVIRON, 2012). A memorandum presenting the 2002 baseline modeling results has been submitted to EPA (ENVIRON, 2013). This memorandum documents the new 2018 base case modeling setup and results.

INTRODUCTION

The Clean Air Act (CAA) establishes special goals for visibility in many national parks, wilderness areas, and international parks. Through the 1977 amendments to the Clean Air Act, Congress set a national goal for visibility as “the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I Federal areas which impairment results from manmade air pollution” (40 CFR 51.300). The goal of the Regional Haze Rule (RHR) is to achieve natural visibility conditions at 156 Federally mandated Class I areas by 2064. To achieve this goal, the RHR has set up milestone years of 2018, 2028, 2038, 2048, 2058, and 2064 to monitor progress toward natural visibility conditions. The 2000-2004 period has been used by states as a baseline from which to demonstrate progress toward natural visibility conditions in 2018.

EPA Region 6 is presently under a court-ordered Consent Decree deadline regarding action on the Texas Regional Haze State Implementation Plan (SIP). Regional haze (RH) is linked to fine particulate matter (PM_{2.5}), for which EPA has a new standard. Air quality modeling is an important tool for determining whether a source can be reasonably expected to contribute to visibility impairment at a Class I area. ENVIRON is assisting EPA to evaluate regional haze impacts of sources in Texas that may be used to support the Texas Regional Haze Implementation Plan.

The Texas RH analysis was built upon the regional photochemical modeling (ENVIRON and CERT, 2007) conducted for CENRAP. In particular, the CENRAP 2002 and 2018 36 km modeling database for CAMx was enhanced to include a 12 km grid over Texas and nearby Class I areas. The overall approach to the project includes the following steps:

- Update CENRAP 2002 and 2018 modeling database to use with the latest release of CAMx (v5.41) when the project began
- Conduct 2002 modeling with Plume-in-Grid (PiG) and a 12-km flexi-nested grid to provide the new 2002 baseline RH modeling
- Conduct 2018 modeling with PiG and the CAMx PM Source Apportionment Technology (PSAT) for target sources selected by EPA
- Evaluate impact of target sources on visibility in Class I areas
- Conduct any additional future-year scenarios to access various control strategies (to be determined)

This memorandum documents the new 2018 base case modeling setup and results.

CAMx MODELING APPROACH

Air quality modeling was performed with version 5.41 of the Comprehensive Air Quality Model with extensions (CAMx; ENVIRON, 2012) with input data developed by CENRAP. The CAMx PM PSAT modeling was also conducted for target sources' SO₂ and NO_x emissions. CAMx has changed since the CENRAP modeling and many CAMx inputs had to be updated. CAMx Input development and updates are described separately below.

2018 Annual 36 km CENRAP modeling database

The Texas RH analysis was built upon the 2018 annual regional photochemical modeling database developed as part of the CENRAP (ENVIRON and CERT, 2007). CENRAP developed a 2018 annual modeling database for CAMx on the 36 km unified national Regional Planning Organization (RPO) grid that covers the continental United States. The CENRAP modeling protocol (Morris et al., 2004), CENRAP modeling Quality Assurance Program Plan (QAPP; Morris and Tonnesen, 2004), and base model evaluation (ENVIRON and CERT, 2007) reports provide details on the development of the CENRAP 2002 and 2018 36 km annual modeling database. Emissions inputs for this study were based on the 2018 Base G (Base18G) which was projected from the 2002 Typical G (Typ02G) inventory. CENRAP went through numerous iterations of the emissions modeling before arriving at the final Base G emission inventories (e.g., Morris et al., 2005).

Enhancement to the CENRAP 2018 Modeling Database

Similar to the 2002 modeling setup, the CENRAP Base G 2018 36 km annual CAMx photochemical modeling database was updated to include a 12 km nested-grid that covers Texas and Class I areas in and near Texas including:

- National Parks: Big Bend (BIBE), Guadalupe Mountains (GUMO), and Carlsbad Caverns;
- Wildlife Refuges: Salt Creek (SACR) and Wichita Mountains (WIMO);
- Wilderness Areas: Breton (BRET), White Mountain (WHIT), Caney Creek (CACR), Upper Buffalo (UPBU), Bandeller (BAND), Hercules-Glade (HEGL), and others (see Table 1).

Figure 1 displays the 36/12 km nested grid for the CAMx modeling. The locations of Interagency Monitoring of Protected Visual Environments (IMPROVE) sites that includes Class I areas within and near the 12 km modeling domain are shown in Figure 2. The CAMx flexi-nesting feature was used to specify a 12 km Texas fine grid within the CENRAP 36 km modeling domain. Full flexi-nesting was invoked in which CAMx internally interpolates meteorological data, gridded emissions and other inputs from the 36 km grid to the 12 km grid. Flexi-nesting does not interpolate point source emissions because exact source coordinates are known enabling each point source to be placed within the correct 36 km or 12 km grid cell.

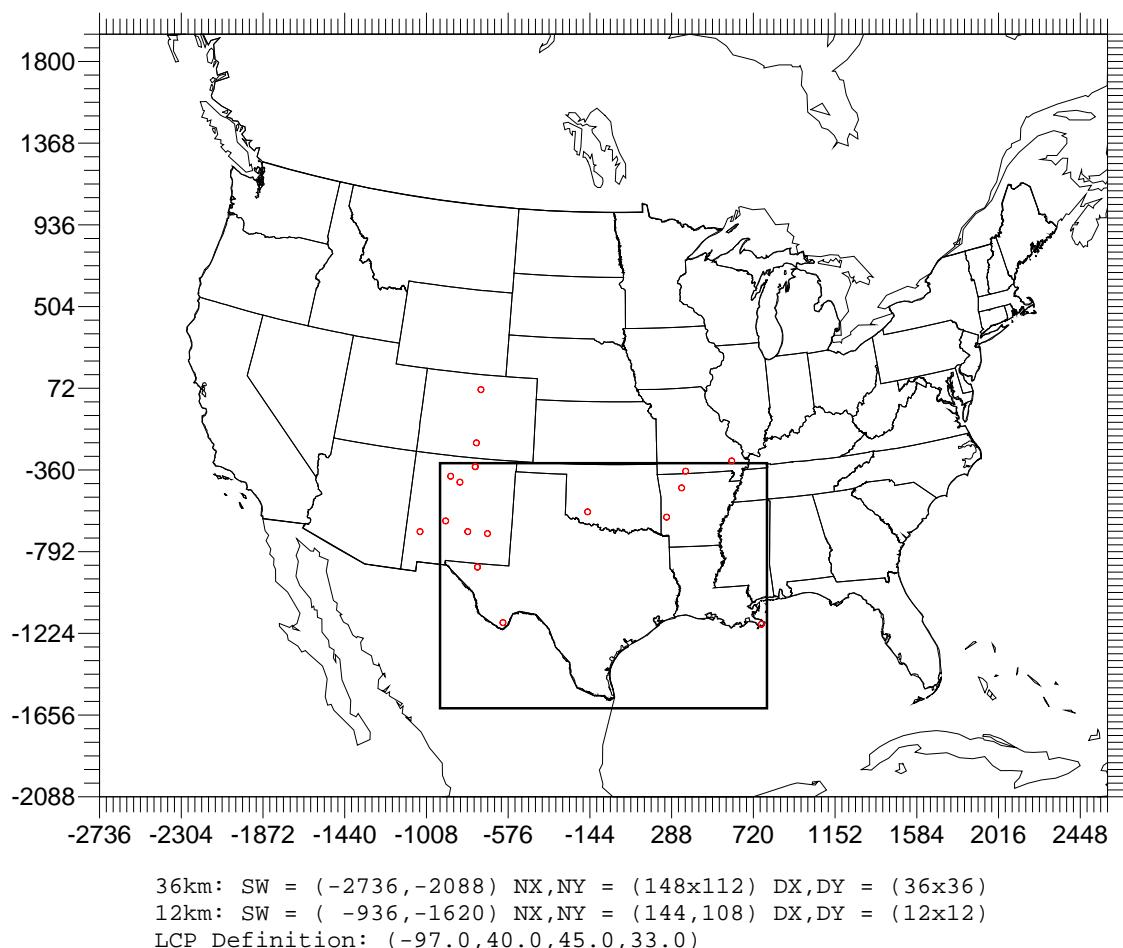


Figure 1. Texas RH modeling 36/12 km modeling domain and the locations of the IMPROVE monitoring sites that include Class I areas, indicated by circles.

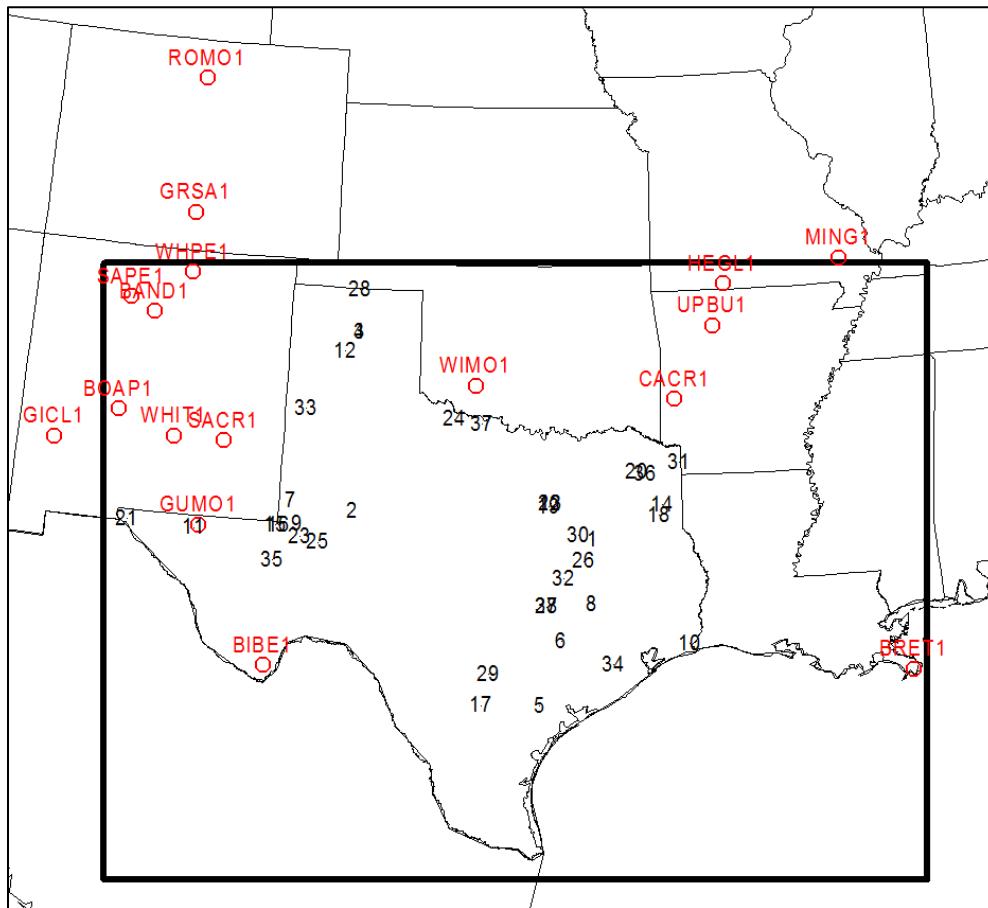


Figure 2. Texas RH modeling 12 km modeling domain, the locations of the IMPROVE monitoring sites (circles) and target sources (indicated by Target ID numbers).

Table 1. Class I areas included in the Texas RH analysis.

Site	State	Code	State FIPS	County	County FIPS	Latitude	Longitude	LCPX (km)	LCPY (km)	Grid
Breton Wilderness Area	LA	BRET1	22	St. Bernard Parish	87	29.1189	-89.2066	763	-1176	12km
Big Bend National Park	TX	BIBE1	48	Brewster County	43	29.3027	-103.178	-604	-1167	12km
Guadalupe Mountains	TX	GUMO1	48	Culberson County	109	31.833	-104.809	-738	-873	12km
Wichita Mountains Wilderness	OK	WIMO1	40	Comanche County	31	34.7323	-98.713	-156	-581	12km
Caney Creek Wilderness Area	AR	CACR1	5	Polk County	113	34.4544	-94.1429	261	-610	12km
Upper Buffalo Wilderness Area	AR	UPBU1	5	Newton County	101	35.8258	-93.203	341	-455	12km
Bandelier Wilderness Area	NM	BAND1	35	Los Alamos County	28	35.7797	-106.266	-831	-424	12km
Bosque del Apache Wilderness Area	NM	BOAP1	35	Socorro County	53	33.8695	-106.852	-906	-629	12km
Carlsbad Caverns NP.	NM	GUMO1				31.833	-104.809	-738	-873	12km

Site	State	Code	State FIPS	County	County FIPS	Latitude	Longitude	LCPX (km)	LCPY (km)	Grid
Gila Wilderness Area	NM	GICL1	35	Catron County	3	33.2204	-108.235	-1042	-686	36km
Pecos Wilderness Area	NM	WHPE1				36.5854	-105.452	-750	-343	12km
Salt Creek Wilderness Area	NM	SACR1	35	Grant County	17	33.4598	-104.404	-685	-696	12km
San Pedro Parks Wilderness Area	NM	SAPE1	35	Rio Arriba County	39	36.0139	-106.845	-880	-393	12km
Wheeler Peak Wilderness Area	NM	WHPE1	35	Taos County	55	36.5854	-105.452	-750	-343	12km
White Mountain Wilderness Area	NM	WHIT1	35	Lincoln County	27	33.4687	-105.535	-790	-686	12km
Hercules-Glades Wilderness Area	MO	HEGL1	29	Taney County	213	36.6138	-92.9221	362	-366	12km
Mingo	MO	MING1	29	Stoddard County	207	36.9717	-90.1432	606	-312	36km
Great Sand Dunes	CO	GRSA1	8	Saguache County	109	37.7249	-105.519	-744	-217	36km
Rocky Mountain National Park	CO	ROMO1	8	Larimer County	69	40.2783	-105.546	-720	65	36km

Preparing Emissions Data

The 2018 emissions were processed consistently with the 2002 emissions. This study used the latest SMOKE version 3.1, although some SMOKE modules came from an older version to maintain compatibility with the format of data from CENRAP. All SMOKE configurations and SMOKE input files were the same as used in CENRAP with selected updates. Provided below is a summary of the emission updates made for this study.

- Updated emissions to 8 facilities and added one new facility:
 - One new unit at Sommers/Deely/Spruce power plant site
 - Two new units at Sandow 5 Generating Plant (new plant)
 - Three new units at WA Parish Station carried over from the 2002 CENRAP inventory and emission changes to one existing unit
 - Emission changes at North Texas Cement (Ash grove) to reflect shutting down two units and rebuilding the third unit
 - Emission changes to reflect recently installed controls on power plants at Sommers/Deely/Spruce, Big Brown, Gibbons Creek, Sandown Steam Electric Station, Monticello Steam Electric Station, and Fayette Power Project
- Used CB05 chemical speciation profiles for area and point sources
- Processed point source emissions in CAMx input format to preserve stack parameters and location
- Changed the earth sphere variable (IOAPI_ISPH) in SMOKE from 19 to 20. CENRAP SMOKE setup used IOAPI_ISPH=19 that could cause inconsistencies between point source locations and the meteorological points. IOAPI_ISPH=20 assumes a 6740 km earth radius consistent with MM5 and CAMx
- Selected Plume-in-Grid (PiG) for large SO₂ and NOx sources

- Assigned PSAT tagging group for each target source
- Added organic aerosol precursor emissions for biogenic sources based on CENRAP BEIS CB4 emissions
- Adjusted primary organic aerosol mass from POC to POA as required by CAMx

The criteria used to specify point sources as elevated and select elevated source for PiG treatment are described below:

Non-Target sources

- A plume rise cutoff of 50 meter (i.e., any source having estimated plume rise lower than 50 m. was treated as a surface source).
- NOx emissions thresholds for PiG selection varied by region: 5 tons per day (TPD) for Texas, 10 TPD for neighboring states (NM, CO, OK, AR, LA, and KS), and 20 TPD for the rest.

Target sources

- All target sources were treated as elevated sources
- PiG criteria are stack height of 50 ft and NOx or SO₂ emissions higher than 20 TPD

Emissions Summary

A summary of emission updates at the unit level is shown in Table 2. Quality assurance of the SMOKE emissions processing conducted for the project included the development of emission summaries based on the raw inventory data input to the SMOKE processing system (IDA files) and daily emission reports from SMOKE. Table 3 summarizes the emission inventory data input to SMOKE from the IDA files (i.e., averages between the ‘winter’ and ‘summer’ files) for 38 target sources. Table 4 presents the emissions data after SMOKE processing. Note differences between the input and output are related to the temporal and spatial allocation within SMOKE, as well as numerical rounding of the data. Specifically, the discrepancies of emissions at two facilities (about 7%), Tolk Station (FIPS 48279; Plant ID 18) and Harrington Station (FIPS 48375; Plant ID 22), are due to temporal processing. Both plants have monthly temporal profiles which are stack-specific. However, from October-December, the CENRAP temporal cross-reference (stack-specific) points to more generic profiles rather than stack-specific profiles.



Table 2. Updates to annual emissions (TPY) of target sources by pollutant in the CENRAP 2018 Base G inventory.

Plant Name	FIPS	Plant ID	Point ID	Stack ID	SCC	CO	VOC	NH3	CENRAP NOx *	CENRAP SO2 *	adjusted NOx	adjusted SO2	PM ₁₀	PM _{2.5}	Note
SOMMERS DEELY SPRUCE PWR	48029	63	95	99	10100226	431.3	88.0	2.3			1158.8	247.1	187.3	119.2	New Unit
SOMMERS DEELY SPRUCE PWR	48029	63	20	20	10100601	189.7	12.4	7.2	198.4	0		3.2	17.5	17.5	Adjusted SO2 emissions
SOMMERS DEELY SPRUCE PWR	48029	63	22	19	10100601	176.7	11.6	6.7	236.7	0		4.6	16.3	16.3	Adjusted SO2 emissions
FAYETTE POWER PROJECT	48149	5	7	7	10100226	632.5	75.9	38.0	2308.0	10534.19		438.3	3431.9	1618.4	Adjusted SO2 emissions
FAYETTE POWER PROJECT	48149	5	8	8	10100226	627.9	75.4	37.7	2695.7	10457.94		451.4	2082.8	1239.9	Adjusted SO2 emissions
FAYETTE POWER PROJECT	48149	5	16	16	10100226	472.1	56.6	28.3	2786.4	2516.258		417.1	1600.5	948.9	Adjusted SO2 emissions
W A PARISH STATION	48157	5	2	23	10100601	4.5	2.1	0			145	0.4	2.9	2.9	New Unit
W A PARISH STATION	48157	5	3	24	10100601	7.2	2	0			73.2	0.4	2.8	2.8	New Unit
W A PARISH STATION	48157	5	4	44	10100601	21.3	2	0			287.5	0.8	2.8	2.8	New Unit
W A PARISH STATION	48157	5	5	26	10100601	272.2	17.8	10.4	202.3	0.0		1.9	25.1	25.1	Adjusted SO2 emissions
BIG BROWN	48161	2	10	10	10100226	652.1	78.3	39.1	3602.6	23327.9	3274.7		236.3	235.2	Adjusted NOx emissions
BIG BROWN	48161	2	11	11	10100226	666.1	79.9	40.0	3754.9	23830.6	3410.1		241.4	240.3	Adjusted NOx emissions
GIBBONS CREEK	48185	2	2	2	10100226	450.1	54.0	27.0	1885.3	2673.2		892.7	540.1	470.9	Adjusted SO2 emissions
SANDOW STEAM ELECTRIC	48331	5	15	16	10100302	1036.6	120.9	51.8	5552.9	8477.0	1386.9		1701.1	1337.6	Adjusted NOx emissions
SANDOW 5 GENERATING PLANT	48331	12	1	1	10100318	150.4	66.0	28.7			757.4	951.2	218.5	200.0	New Unit
SANDOW 5 GENERATING PLANT	48331	12	2	2	10100318	93.6	66.0	27.7			772.0	1012.8	243.9	104.9	New Unit
MONTICELLO STM ELE STN	48449	3	9	9	10100226	555.0	66.6	33.3	4589.1	19853.3	3427.7		201.0	200.1	Adjusted NOx emissions
MONTICELLO STM ELE STN	48449	3	10	10	10100301	610.3	170.9	73.2	5880.8	11977.7	5742.8		1100.9	983.9	Adjusted NOx emissions
NORTH TEXAS CEMENT CO.	48139	2	2	9	30500706	0	0	0	0	0	0	0	0	0	Shut down
NORTH TEXAS CEMENT CO.	48139	2	10	8	30500706	0	0	0	0	0	0	0	0	0	Shut down
NORTH TEXAS CEMENT CO.	48139	2	9	7	30500706	0	0	0	0	0	0	0	0	0	Shut down
NORTH TEXAS CEMENT CO.	48139	2	99	7	30500706	581.3	65.5	77.5			711.8	189.8	161.8	159.9	New Unit

*CENRAP emissions that were adjusted are highlighted in blue; emissions from new units are highlighted in red

Table 3. Annual emissions (TPY) of target sources by pollutant in the updated 2018 base case inventory (before SMOKE processing).

Target ID	Plant Name	FIPS	Plant ID	NOX	CO	VOC	SO2	PM _{2.5}	PM ₁₀
1	BIG BROWN	48161	2	6,697	1,322	158	47,159	495	540
2	BIG SPRING CARBON BLACK	48227	2	1,135	7,083	68	17,823	9	137
3	BORGER CARBON BLACK	48233	1	636	17,475	580	4,338	105	147
4	BORGER CARBON BLACK PLT	48233	2	1,048	965	3	6,564	164	360
5	COLETO CREEK PLANT	48175	2	4,295	509	61	16,225	425	514
6	FAYETTE POWER PROJECT	48149	5	7,792	1,733	224	1,307	3,849	7,208
7	FULLERTON GAS PLANT	48003	10	1,861	966	406	3,040	29	29
8	GIBBONS CREEK	48185	2	1,885	450	54	893	474	549
9	GOLDSMITH GASOLINE PLANT	48135	22	1,129	691	259	1,916	9	9
10	GREAT LAKES CARBON LLC	48245	23	824	56	6	12,881	234	322
11	GUADALUPE COMPRESSOR STATION								
		48109	5	850	130	1	3	5	5
12	HARRINGTON STATION	48375	22	5,581	1,132	136	22,892	586	724
13	HOLCIM (TEXAS) LP	48139	22	5,018	7,198	823	4,518	562	563
14	HW PIRKEY POWER PLT	48203	22	4,902	524	147	19,635	1,298	1,629
15	KEYSTONE COMPRESSOR STN.	48495	30	3,654	788	77	0	24	24
16	KEYSTONE PLANT	48495	6	2,809	455	173	672	37	37
17	LIGNITE-FIRED POWER PLANT	48013	7	4,213	336	136	6,603	1,338	1,745
18	MARTIN LAKE ELECTRICAL STATION								
		48401	11	19,035	4,407	515	36,027	3,118	3,525
19	MIDLOTHIAN PLANT	48139	9	6,067	1,175	66	3,263	174	457
20	MONTICELLO STM ELE STN	48449	3	12,241	1,706	302	51,133	1,400	1,567
21	NEWMAN STATION	48141	8	50	64	2	0	5	5
22	NORTH TEXAS CEMENT CO.	48139	2	712	581	67	190	348	397
23	ODESSA CEMENT PLANT	48135	23	2,510	1,850	169	469	199	429
24	OKLAUNION POWER STATION	48487	10	6,303	747	90	7,158	764	870
25	PEGASUS GAS PLANT	48329	6	2,666	538	248	107	9	9
26	RELIANT ENERGY LIMESTONE	48293	10	10,907	2,413	288	17,840	2,144	2,502
27	SANDOW STEAM ELECTRIC	48331	5	1,400	1,039	121	8,503	1,340	1,708
28	SHERHAN PLANT	48195	6	3,079	926	374	685	43	43
29	SOMMERS DEELY SPRUCE PWR	48029	63	8,176	1,969	255	26,309	1,767	2,849
30	STREETMAN PLANT	48349	11	973	302	400	4,886	116	214
31	TEXARKANA MILL	48067	5	2,359	1,066	1,933	557	772	858
32	TNP ONE STEAM ELECTRIC ST	48395	13	2,343	12,670	35	1,687	282	394
33	TOLK STATION	48279	18	5,253	1,078	130	22,133	486	603
34	W A PARISH STATION	48157	5	4,393	2,534	291	15,478	2,256	2,501
35	WAHA PLANT	48389	2	594	344	60	4,060	53	53
36	WELSH POWER PLANT	48449	5	6,171	1,477	177	14,284	1,553	1,790
37	WORKS NO 4	48485	15	8,929	18	1	623	634	666
38	SANDOW 5 GENERATING PLANT	48331	12	1,529	244	132	1,964	305	462

Table 4. Annual emissions (TPY) of target sources by pollutant in the updated 2018 base case inventory (after SMOKE processing).

Target ID	Plant Name	FIPS	Plant ID	NOX	CO	VOC	SO2	PM _{2.5}	PM ₁₀
1	BIG BROWN	48161	2	6,688	1,313	157	46,998	492	537
2	BIG SPRING CARBON BLACK	48227	2	1,135	7,083	68	17,891	9	137
3	BORGER CARBON BLACK	48233	1	636	17,475	580	4,919	105	147
4	BORGER CARBON BLACK PLT	48233	2	1,048	965	3	6,568	164	360
5	COLETO CREEK PLANT	48175	2	4,267	506	61	16,182	423	511
6	FAYETTE POWER PROJECT	48149	5	7,728	1,719	222	1,527	3,819	7,153
7	FULLERTON GAS PLANT	48003	10	1,861	966	406	3,445	29	29
8	GIBBONS CREEK	48185	2	1,872	447	54	945	471	546
9	GOLDSMITH GASOLINE PLANT	48135	22	1,129	691	259	2,174	9	9
10	GREAT LAKES CARBON LLC	48245	23	824	56	6	12,887	234	322
11	GUADALUPE COMPRESSOR STATION								
		48109	5	850	130	1	4	5	5
12	HARRINGTON STATION	48375	22	5,136	1,042	125	21,175	543	671
13	HOLCIM (TEXAS) LP	48139	22	5,018	7,198	823	5,340	562	563
14	HW PIRKEY POWER PLT	48203	22	4,889	523	146	19,729	1,295	1,625
15	KEYSTONE COMPRESSOR STN.	48495	30	3,654	788	77	78	25	25
16	KEYSTONE PLANT	48495	6	2,809	455	173	845	37	37
17	LIGNITE-FIRED POWER PLANT	48013	7	4,197	335	136	6,714	1,333	1,739
18	MARTIN LAKE ELECTRICAL STATION								
		48401	11	18,911	4,380	512	36,316	3,099	3,503
19	MIDLOTHIAN PLANT	48139	9	6,067	1,175	66	3,329	174	457
20	MONTICELLO STM ELE STN	48449	3	12,209	1,693	300	51,028	1,391	1,558
21	NEWMAN STATION	48141	8	48	62	2	0	5	5
22	NORTH TEXAS CEMENT CO.	48139	2	712	581	67	256	348	397
23	ODESSA CEMENT PLANT	48135	23	2,510	1,850	169	639	199	429
24	OKLAUNION POWER STATION	48487	10	6,302	747	90	7,247	764	870
25	PEGASUS GAS PLANT	48329	6	2,666	538	248	355	9	9
26	RELIANT ENERGY LIMESTONE	48293	10	10,855	2,402	287	18,044	2,134	2,490
27	SANDOW STEAM ELECTRIC	48331	5	1,400	1,033	120	8,574	1,332	1,699
28	SHERHAN PLANT	48195	6	3,079	926	374	1,060	43	43
29	SOMMERS DEELY SPRUCE PWR	48029	63	8,168	1,942	253	26,749	1,774	2,865
30	STREETMAN PLANT	48349	11	973	302	400	5,286	116	214
31	TEXARKANA MILL	48067	5	2,358	1,066	1,933	2,490	772	858
32	TNP ONE STEAM ELECTRIC ST	48395	13	2,327	12,586	35	1,711	281	392
33	TOLK STATION	48279	18	4,883	1,002	120	20,683	453	564
34	W A PARISH STATION	48157	5	4,454	2,636	297	15,669	2,252	2,496
35	WAHA PLANT	48389	2	594	344	60	4,119	53	53
36	WELSH POWER PLANT	48449	5	6,126	1,466	176	14,354	1,541	1,776
37	WORKS NO 4	48485	15	8,929	19	1	624	634	666
38	SANDOW 5 GENERATING PLANT	48331	12	1,527	244	132	1960	304	462

Other CAMx Inputs

All other CAMx inputs including meteorological data, land-use files, albedo-haze-ozone inputs, photolysis rates, boundary and initial conditions were the same as used in the 2002 baseline modeling.

CAMx Model Configuration

The CAMx configuration was the same as used in the 2002 baseline modeling except that the PSAT source tagging feature was turned on (Table 4). The CAMx model was run separately for each of four quarters of 2018 using a 15 day spin up period to limit the influence of the assumed initial concentrations.

Table 4. Model Configurations Options for CAMx model.

Science Options	Texas RH
Version	Version 5.41
Vertical Grid Mesh	19 Layers
Horizontal Grids	36/12 km using two-way nesting
Initial Conditions	15 days full spin-up
Boundary Conditions	2002 GEOS-CHEM day specific 3-hour average data
Sub-grid-scale Plumes	PiG treatment
Chemistry	
Gas Phase Chemistry	CB05
Aerosol Chemistry	ISORROPIA equilibrium
Secondary Organic Aerosols	SOAP
Cloud Chemistry	RADM-type aqueous chemistry
Meteorological Processor	MM5CAMx v5.2
Horizontal Transport	
Eddy Diffusivity Scheme	K-theory with Kh grid size dependence
Source Apportionment	PSAT (sulfur, nitrogen, and primary PM)
Vertical Transport	
Eddy Diffusivity Scheme	K-Theory
Diffusivity Lower Limit	Kzmin = 0.1 to 1.0 (Land use dependent Kzmin)
Planetary Boundary Layer	From MM5 with PBL below convective clouds raised to cloud top
Deposition Scheme	Zhang
Numerics	
Gas Phase Chemistry Solver	Euler Backward Iterative (EBI) solver
Horizontal Advection Scheme	Piecewise Parabolic Method (PPM scheme)
Parallelization	OMP-MPI

PSAT Formulation

PSAT is designed to source apportion the following PM species modeled in CAMx:

- Sulfate (SO₄)
- Particulate nitrate (NO₃)
- Ammonium (NH₄)
- Particulate mercury (Hg(p))
- Secondary organic aerosol (SOA)
- Six categories of primary particulate matter (PM)
 - Elemental carbon (EC)
 - Primary organic aerosol (POA)
 - Fine crustal PM (FCRS)
 - Fine other primary PM (FPRM)
 - Coarse crustal PM (CCRS)
 - Coarse other primary PM (CPRM)

PSAT performs PM source apportionment (also called source tagging) for each selected source group. A source group may consist of a combination of geographic regions and emissions source categories. For this study, each target facility is assigned a unique PSAT source group. The PSAT “reactive tracers” that are added for each source group (*i*) are described below. In general, a single tracer can track primary PM species, whereas secondary PM species require several tracers to track the relationship between gaseous precursors and the resulting PM. Particulate nitrate and secondary organics are the most complex species to apportion because the emitted precursor gases (NO_x and VOCs) are several steps removed from the resulting PM species (NO₃ and SOA). There is a PSAT convention that tracer names for particulate species begin with the letter “P.” This study tracks sulfur, nitrogen and primary particulate matter tracers:

Sulfur (SO₄ Tracers)

- SO₂_i Primary SO₂ emissions
- PS4_i Particulate sulfate ion from primary emissions plus secondarily formed sulfate

Nitrogen (NO₃ Tracers)

- RGN_i Reactive gaseous nitrogen including primary NO_x (NO + NO₂) emissions plus nitrate radical (NO₃), nitrous acid (HONO) and dinitrogen pentoxide (N₂O₅).
- TPN_i Gaseous peroxy acetyl nitrate (PAN) plus peroxy nitric acid (PNA)
- NTR_i Organic nitrates (RNO₃)
- HN3_i Gaseous nitric acid (HNO₃)
- PN3_i Particulate nitrate ion from primary emissions plus secondarily formed nitrate
- NH3_i Gaseous ammonia (NH₃)
- PN4_i Particulate ammonium (NH₄)

Primary Particulate Matter (PM Tracers)

- PEC_i Primary Elemental Carbon
- POA_i Primary Organic Aerosol

PFC_i Fine Crustal PM
 PFN_i Other Fine Particulate
 PCC_i Coarse Crustal PM
 PCS_i Other Coarse Particulate

One fundamental assumption in PSAT is that PM is apportioned back to the primary precursor for each type of PM. For example, SO₄ is apportioned to SO_x emissions, NO₃ is apportioned to NO_x emissions, NH₄ is apportioned to NH₃ emissions, etc.

CAMx MODELING RESULTS

Air quality modeling results for the 2018 base case simulation are presented by pollutant of concern, including ozone and PM. The analysis of air quality results focuses on high ozone and PM levels, i.e. maximum 8-hour ozone and maximum 24-hour PM. Annual average levels for PM and its constituents are also presented. This section also provides analysis of visibility contribution at Class I areas due to target sources. Comparison of a reasonable progress goal to a glide slope for each Class I area is provided at the end of this section.

Ozone

The annual maximum 8-hour ozone may be susceptible to emissions/model artifacts and so we focus on the annual 4th highest 8-hour ozone (Figure 3). Similar to the 2002 results, the 2018 base case shows high values of 4th highest daily maximum 8-hour ozone (above 75 ppb, the current level of the ozone NAAQS) in several western locations associated with wildfire emissions and over water bodies close to major urban/industrial areas near the Great Lakes, Gulf Coast and the Northeast Seaboard, where emissions are transported over water and confined to a shallow boundary layer. The 2018 ozone is lower than the 2002 ozone in most eastern states. Nonetheless, ozone exceeds 75 ppb in several urban areas in Texas including Dallas and Houston. New Orleans and Baton Rouge, Louisiana, also exceed over 75 ppb.

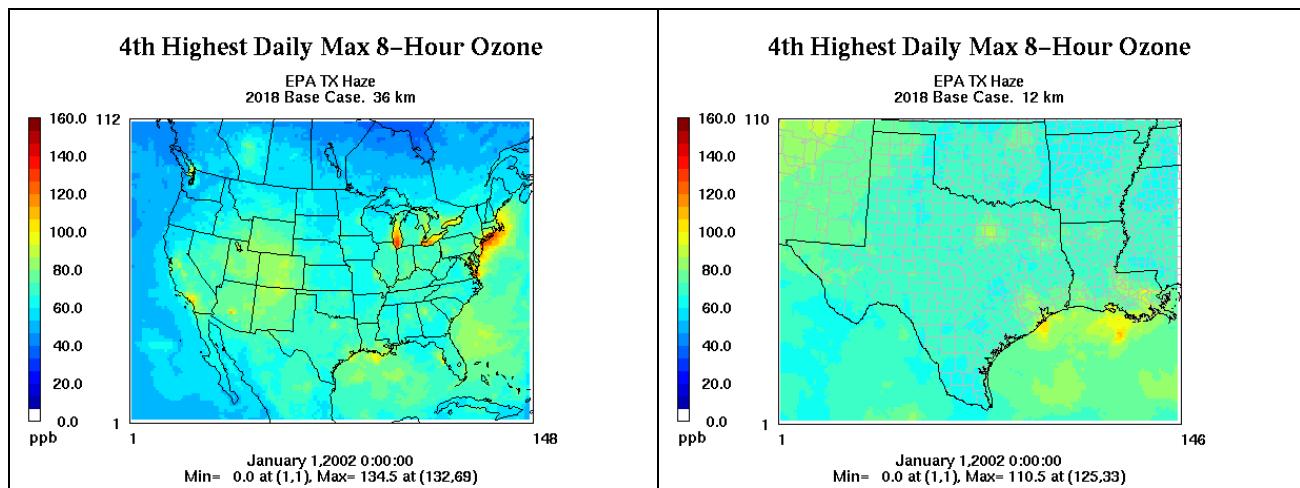


Figure 3. 4th highest daily maximum 8-Hour ozone (ppb) from the 36-km simulation (left) and 12-km simulation (right) for the 2018 base case.

Particulate Matter

PM_{2.5} results are presented for daily design-value relevant measures (98th percentile of all daily concentrations) and annual average concentrations. Overall, the 2002 and 2018 results have similar spatial patterns but the 2018 PM_{2.5} concentrations are lower. The 8th highest 24-hour average concentrations of PM_{2.5} (Figure 4) shows the highest peak values occurring in the Western United States but more uniformly high values occurring in the Eastern United States. Elevated PM_{2.5} concentrations in the 12 km domain are seen in western Louisiana and western Arkansas due to fire activities (also observed in the 2002 simulation). Similar PM compositions to the 2002 simulation are seen in the 2018 simulation (show in Appendix A). Specifically, high particulate matter concentrations in the Eastern United States have large sulfate and nitrate contributions with additional contributions from primary organic PM in the south. Urban PM_{2.5} in Texas (characterized by high nitrate and organic carbon) is lower in the 2018 simulation. Annual average concentrations of PM_{2.5} and PM₁₀ (Figure 5 and Figure 6) show a similar pattern of widespread but the fire influence is less pronounced.

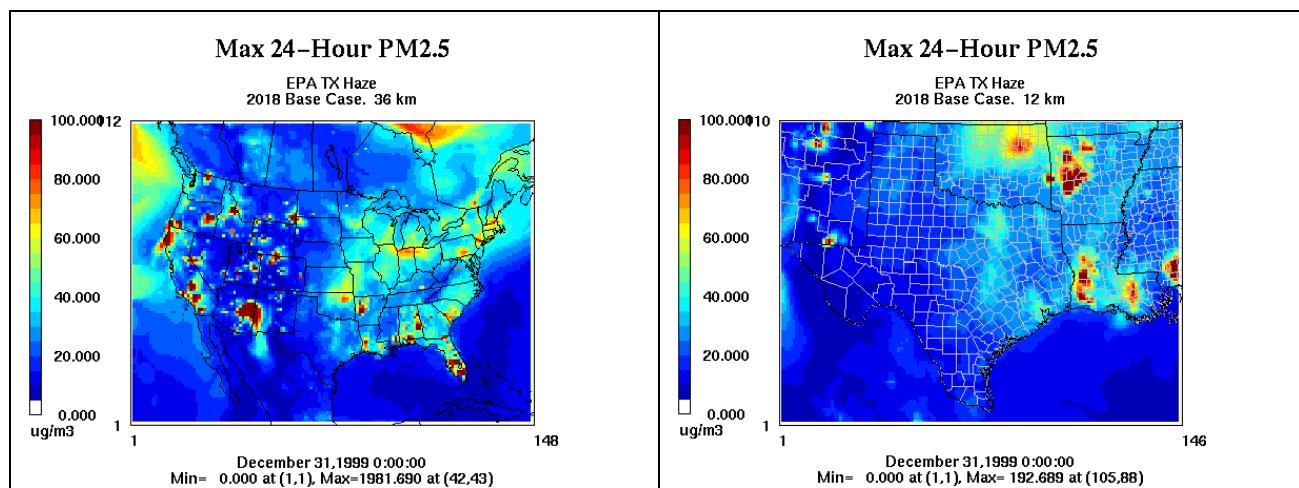


Figure 4. Maximum 24-Hour PM_{2.5} ($\mu\text{g m}^{-3}$) from the 36-km simulation (left) and 12-km simulation (right) for the 2018 base case.

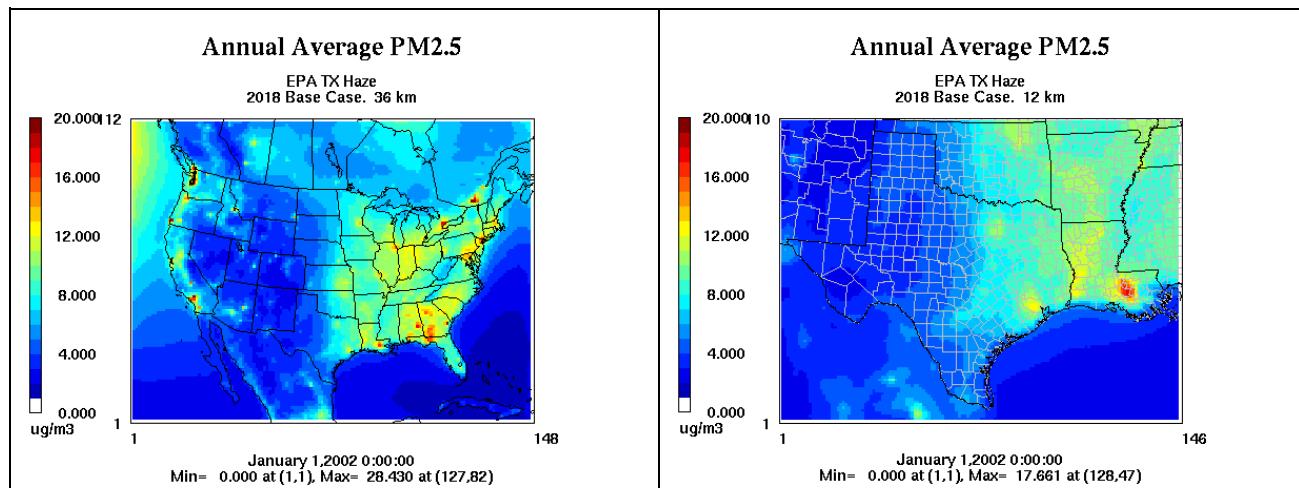


Figure 5. Annual average PM_{2.5} ($\mu\text{g m}^{-3}$) from the 36-km simulation (left) and 12-km simulation (right) for the 2018 base case.

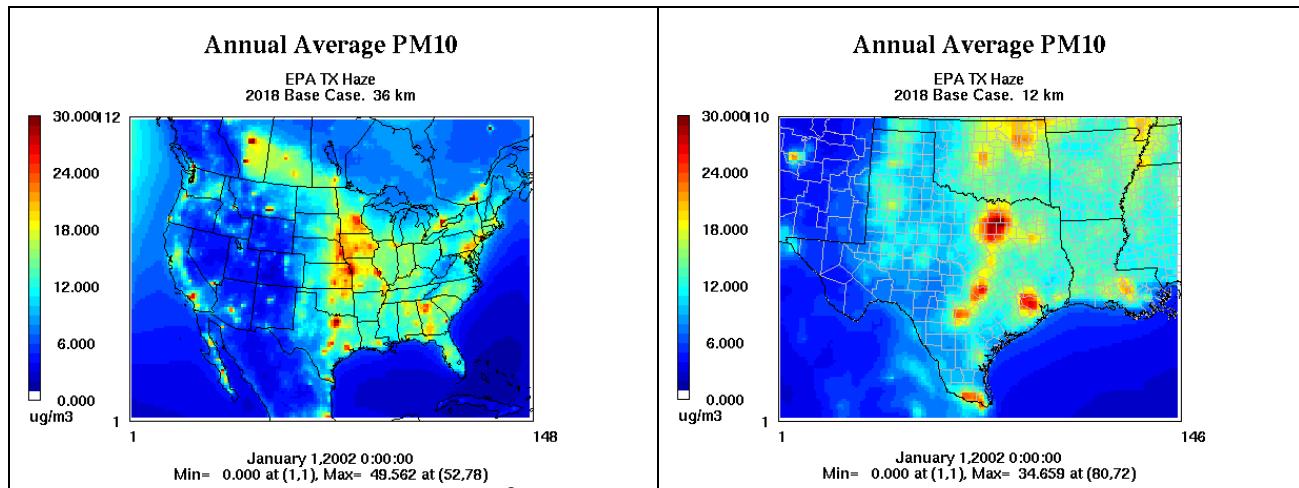


Figure 6. Annual average PM₁₀ ($\mu\text{g m}^{-3}$) from the 36-km simulation (left) and 12-km simulation (right) for the 2018 base case.

Visibility Contributions

Visibility impacts were calculated at each Class I area using 2018 PM concentrations from each PSAT group. Steps in conducting visibility contribution calculations are summarized below:

- Step 1. Use Modeled Attainment Test Software (MATS) to compute model-estimated relative response factors (RRFs) that are the ratio of the model-estimated 24-hour PM_{2.5} concentrations for the future-year (2018) to the baseline (2002) emission scenarios.
- Step 2. Calculate 2018 modeled visibility conditions and projected visibility conditions (using RRF approach) for 20% worst (W20%) and 20% best (B20%) days
- Step 3. To get individual source or group of sources contributions, subtract the PSAT results from the 2018 CAMx output for the source of interest, rerun MATS, and calculate differences of projected visibility conditions by repeating Step 2.

These procedures use the new IMPROVE algorithm (Pitchford et al., 2007) which reconstructs the light-extinction coefficient (b_{ext} , expressed in units of inverse megameters, Mm⁻¹) using the following equation:

$$\begin{aligned}
 b_{\text{ext}} \approx & \\
 & 2.2 \times f_S(\text{RH}) \times [\text{small sulfate}] + 4.8 \times f_L(\text{RH}) \times [\text{large sulfate}] \\
 & + 2.4 \times f_S(\text{RH}) \times [\text{small nitrate}] + 5.1 \times f_L(\text{RH}) \times [\text{large nitrate}] \\
 & + 2.8 \times [\text{small organic mass}] + 6.1 \times [\text{large organic mass}] \\
 & + 10 \times [\text{elemental carbon}] \\
 & + 1 \times [\text{fine soil}] \\
 & + 1.7 \times f_{SS}(\text{RH}) \times [\text{sea salt}] \\
 & + 0.6 \times [\text{coarse mass}] \\
 & + \text{Rayleigh scattering (site-specific)} \\
 & + 0.33 \times [\text{NO}_2 (\text{ppb})]
 \end{aligned}$$

The apportionment of the total concentration of sulfate compounds into the concentrations of small and large size fractions is accomplished using the following equations:

$$[\text{large sulfate}] = [\text{total sulfate}/20] \times [\text{total sulfate}], \text{ for } [\text{total sulfate}] < 20 \mu\text{g/m}^3$$

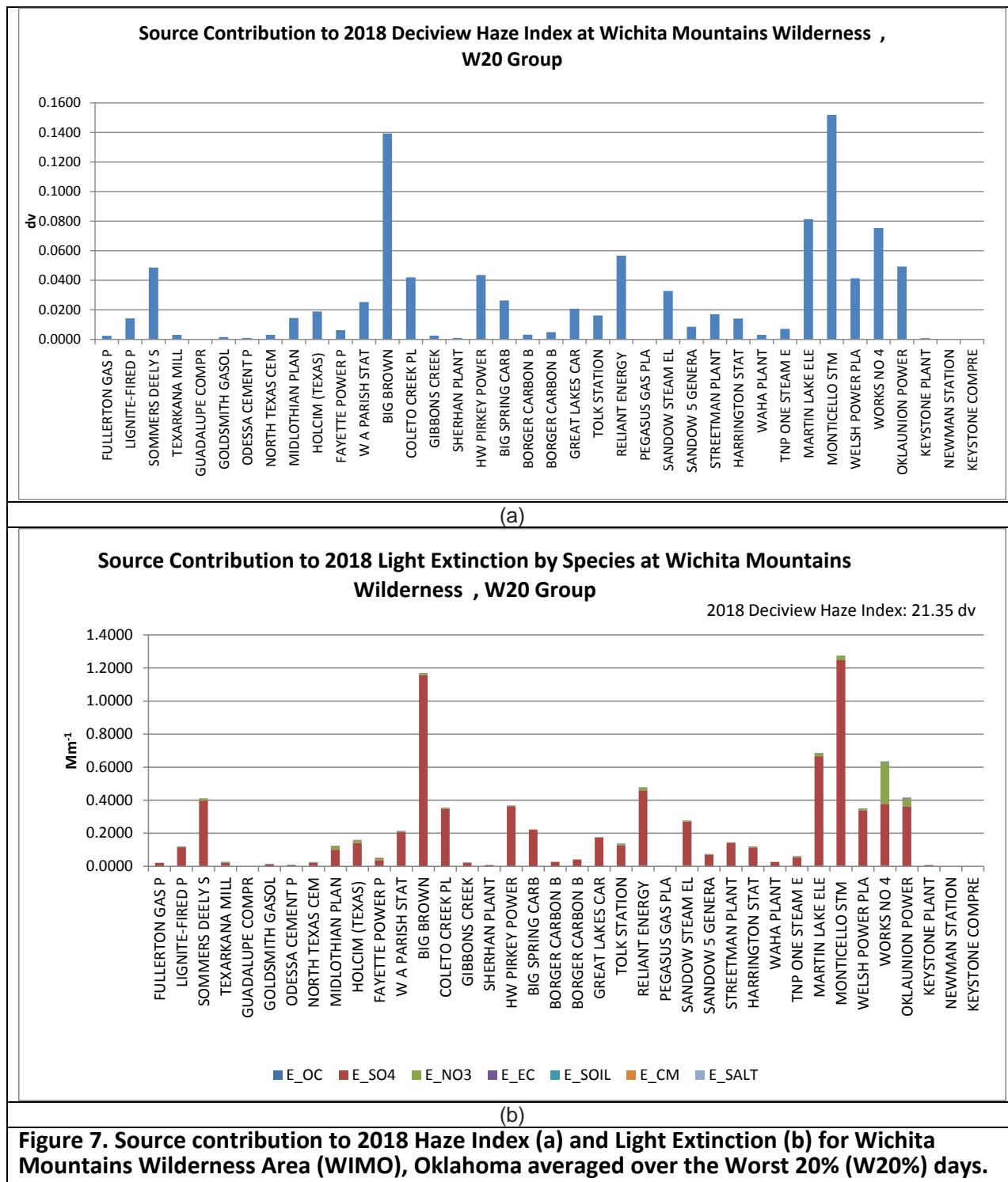
$$[\text{large sulfate}] = [\text{total sulfate}], \text{ for } [\text{total sulfate}] \geq 20 \mu\text{g/m}^3$$

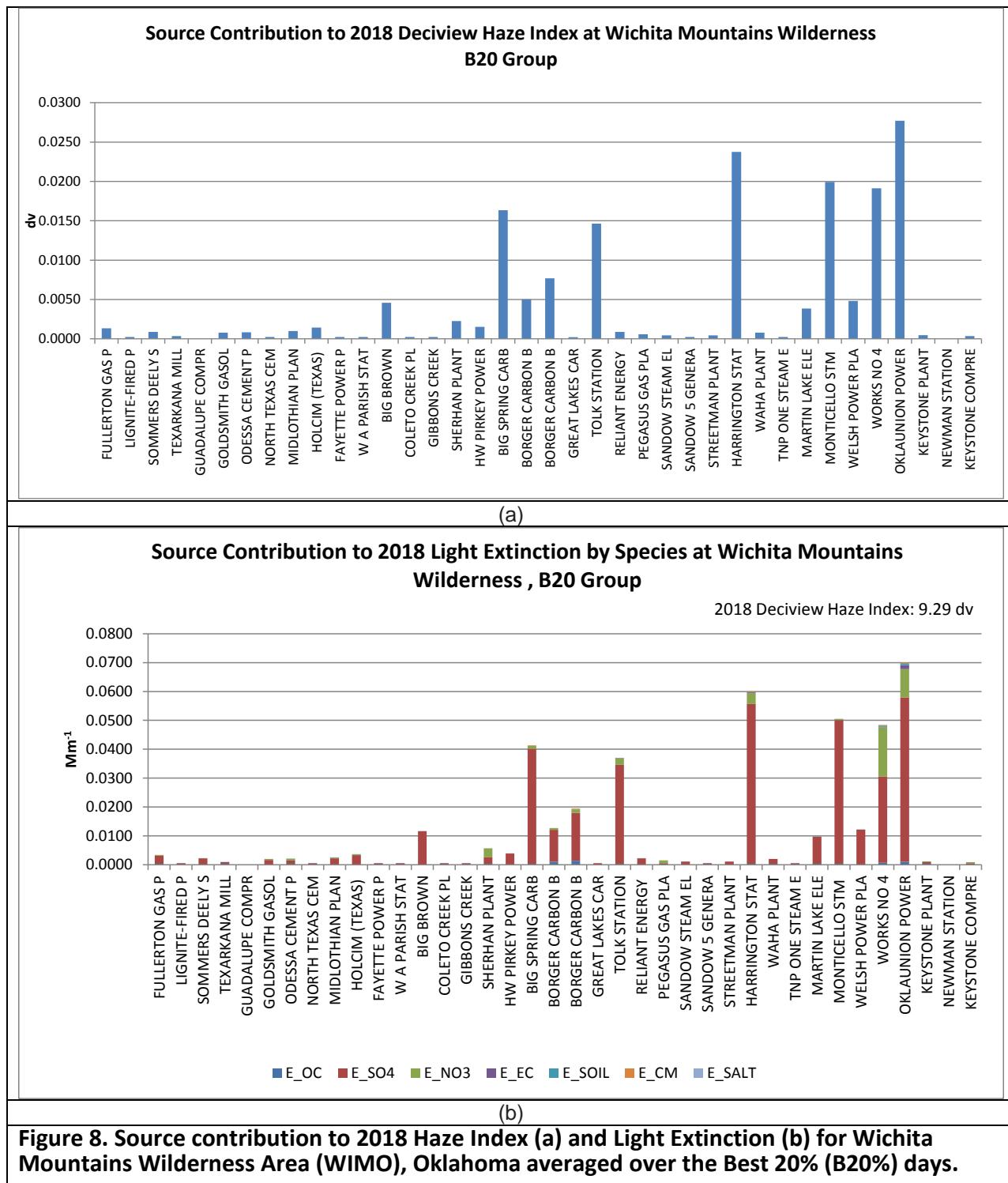
$$[\text{small sulfate}] = [\text{total sulfate}] - [\text{large sulfate}]$$

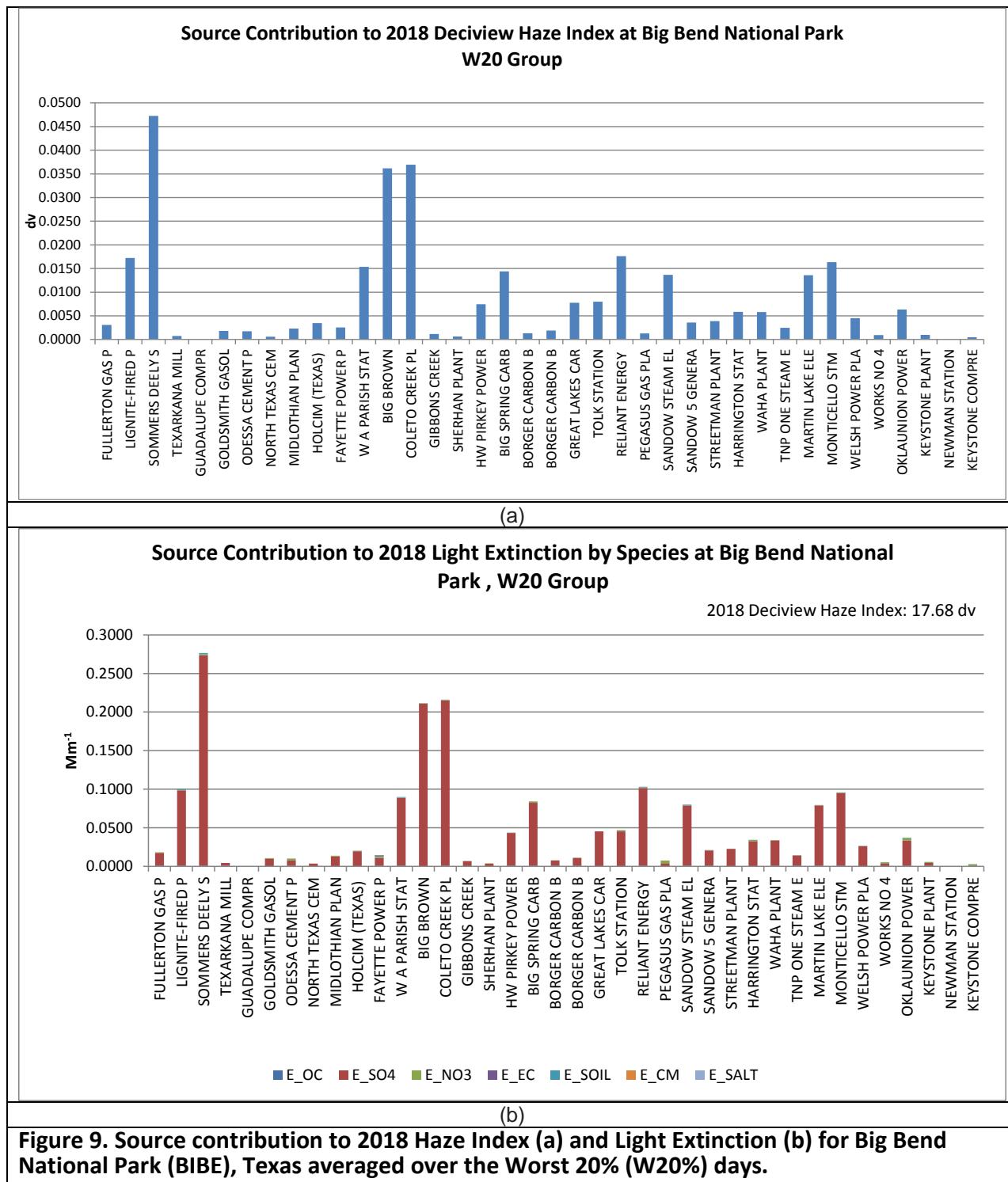
Similar equations are used to apportion total nitrate and total organic mass into small and large size fractions. The new algorithm contains three distinct water growth terms, designated f_S , f_L , and f_{SS} for the small and large sulfate and nitrate fractions, and for sea salt, respectively. Monthly average $f(RH)$ values are used as following FLAG2010 procedure (FLAG, 2010).

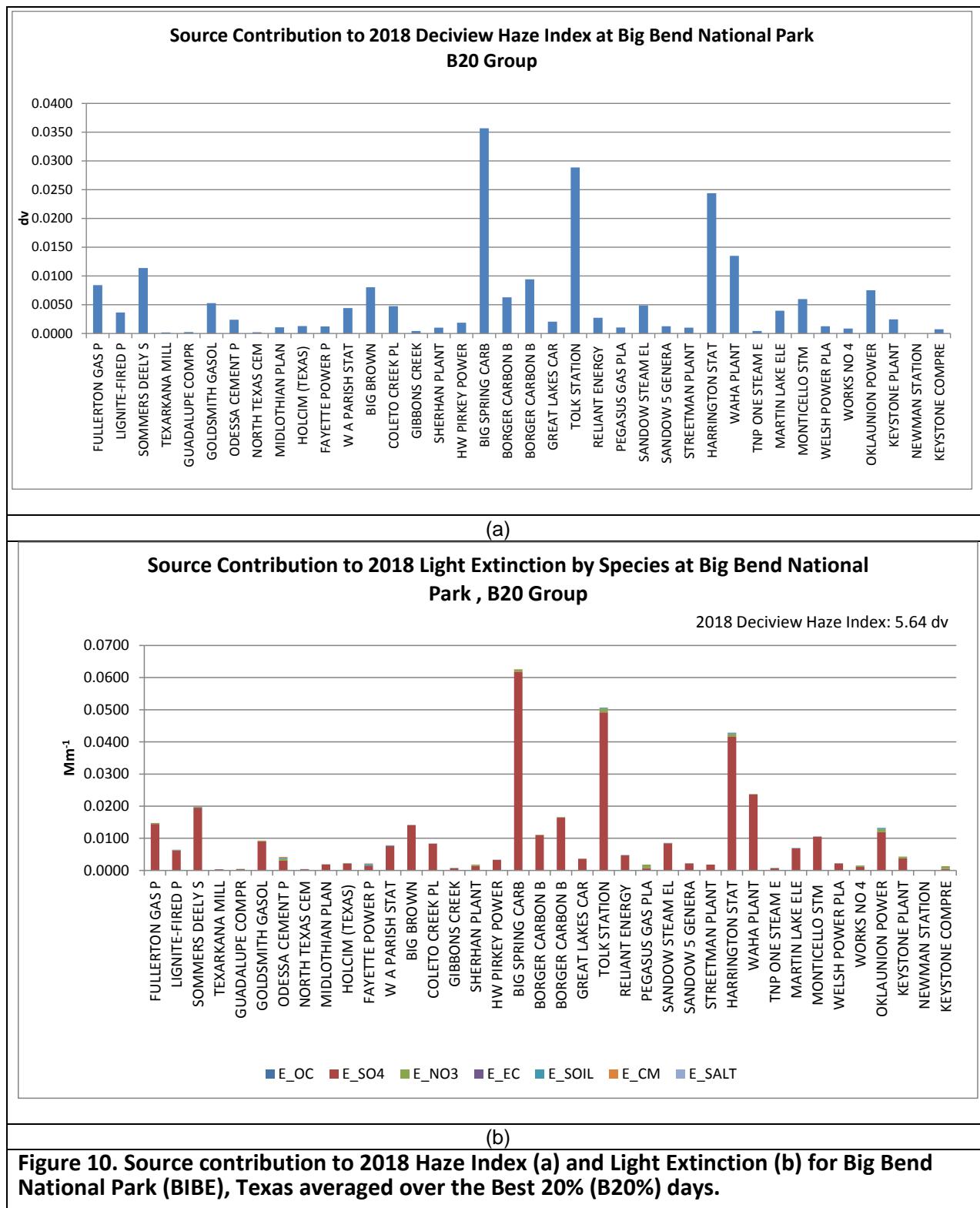
Our analysis calculates the day-specific visibility impacts at Class I areas on the B20% and W20% days. Figures 7-14 demonstrate visibility contributions at the Class I areas in Texas (i.e., Big Bend and Guadalupe Mountains) and near Texas (i.e., Caney Creek and White Mountain) averaged over the B20% and W20% days. Additional types of graphics showing visibility contributions can be found in Appendix B and in supporting Excel Spreadsheets accompanying this memorandum.

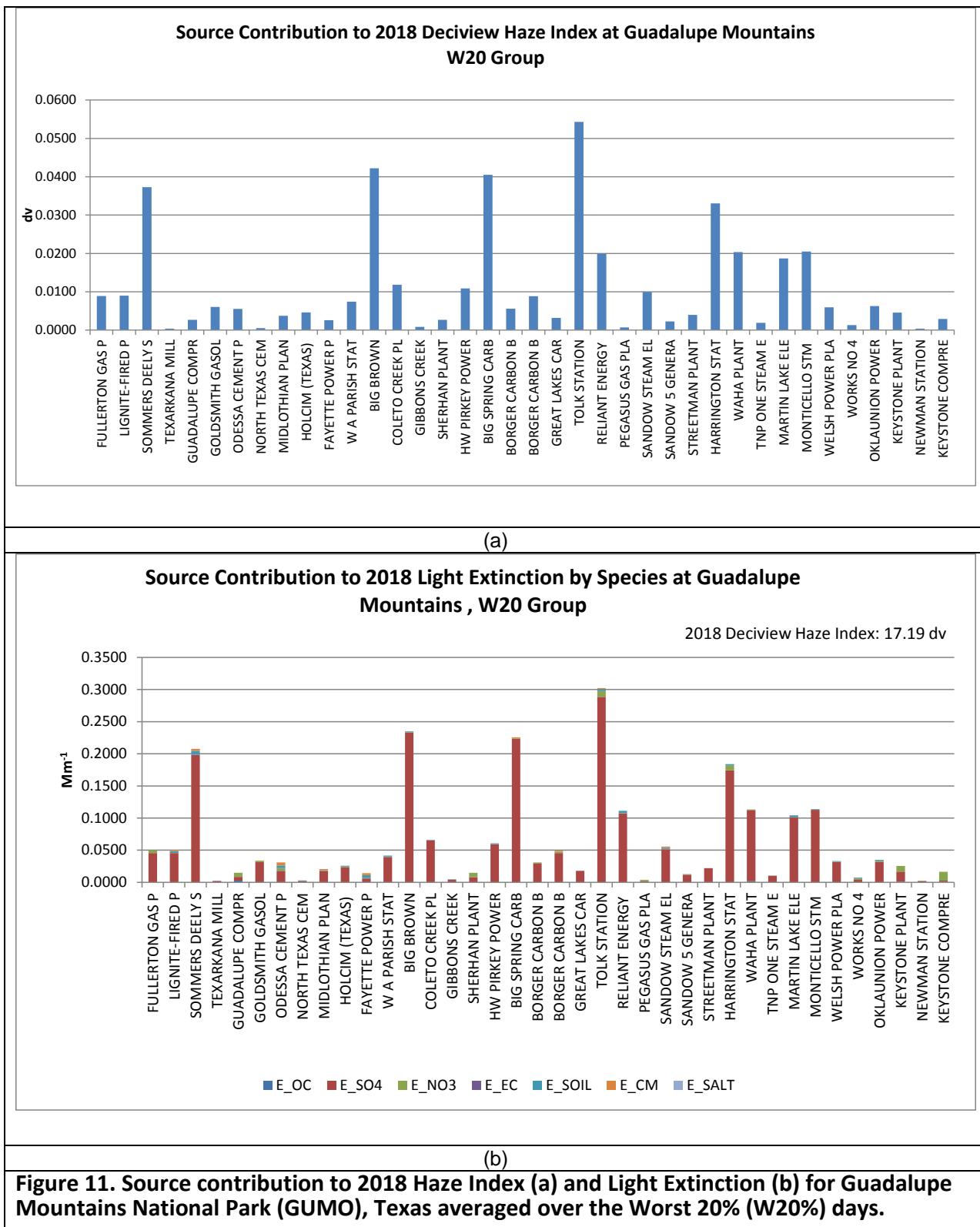
Sulfate appears to be the main constituent that contributes to visibility degradation at the Class I areas in/near Texas on both B20% and W20% cases. Although the 2002 visibility model performance shows underestimation of sulfate across all sites on the W20% days, the RRF approach makes use of model results in a relative sense to counter the model biases. The B20% days generally include more winter days than the W20% days, resulting in higher visibility contributions from nitrate. Proximity of target sources to Class I areas and magnitude of SO_2 emissions are factors that influence visibility impacts at these four Class I areas. A sensitivity test showed that projected visibility conditions and contributions are relatively unaffected by using an alternate RRF approach with RRF for coarse material and soil set to 1 (not shown here) on both 20% worst and 20% best days.

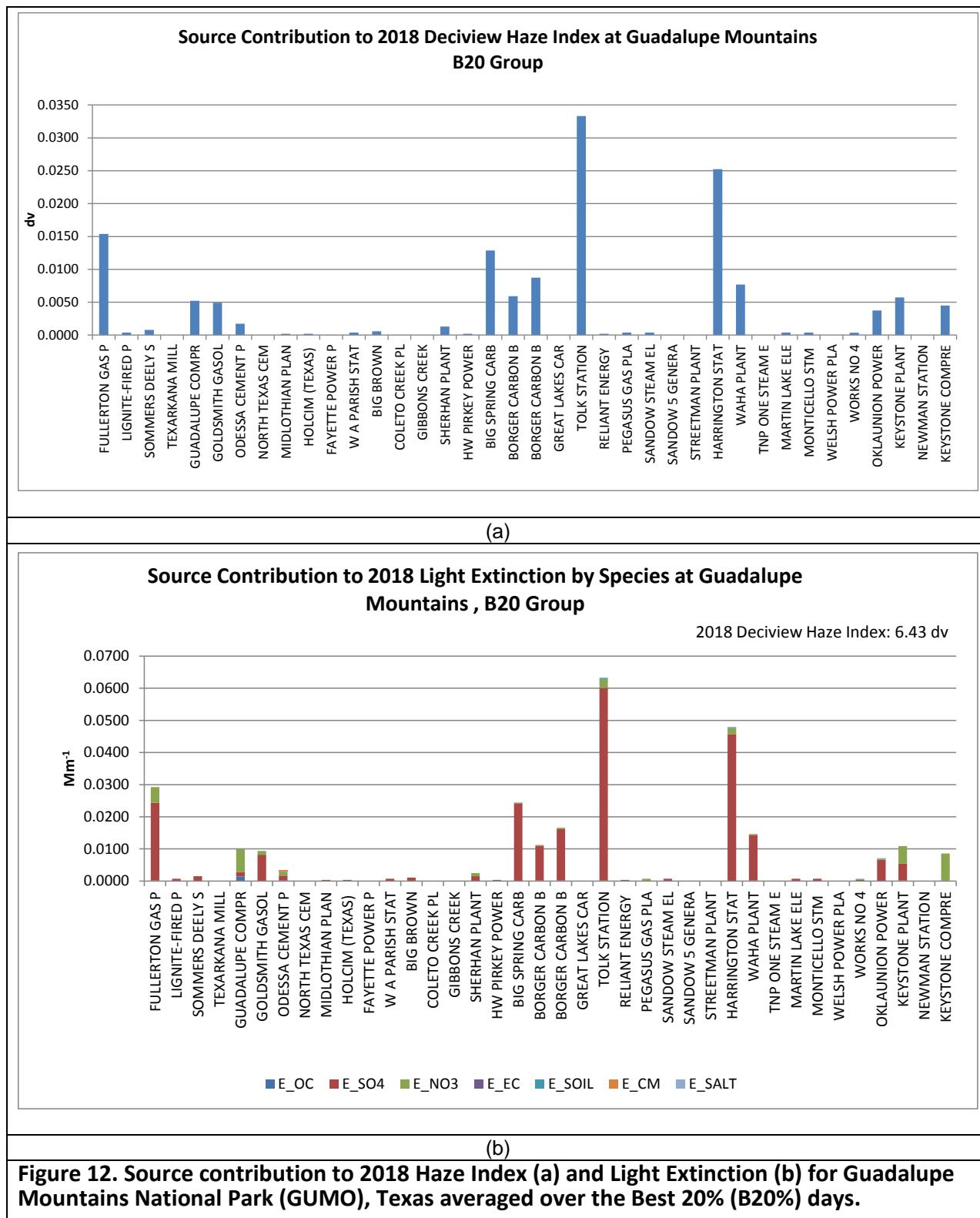


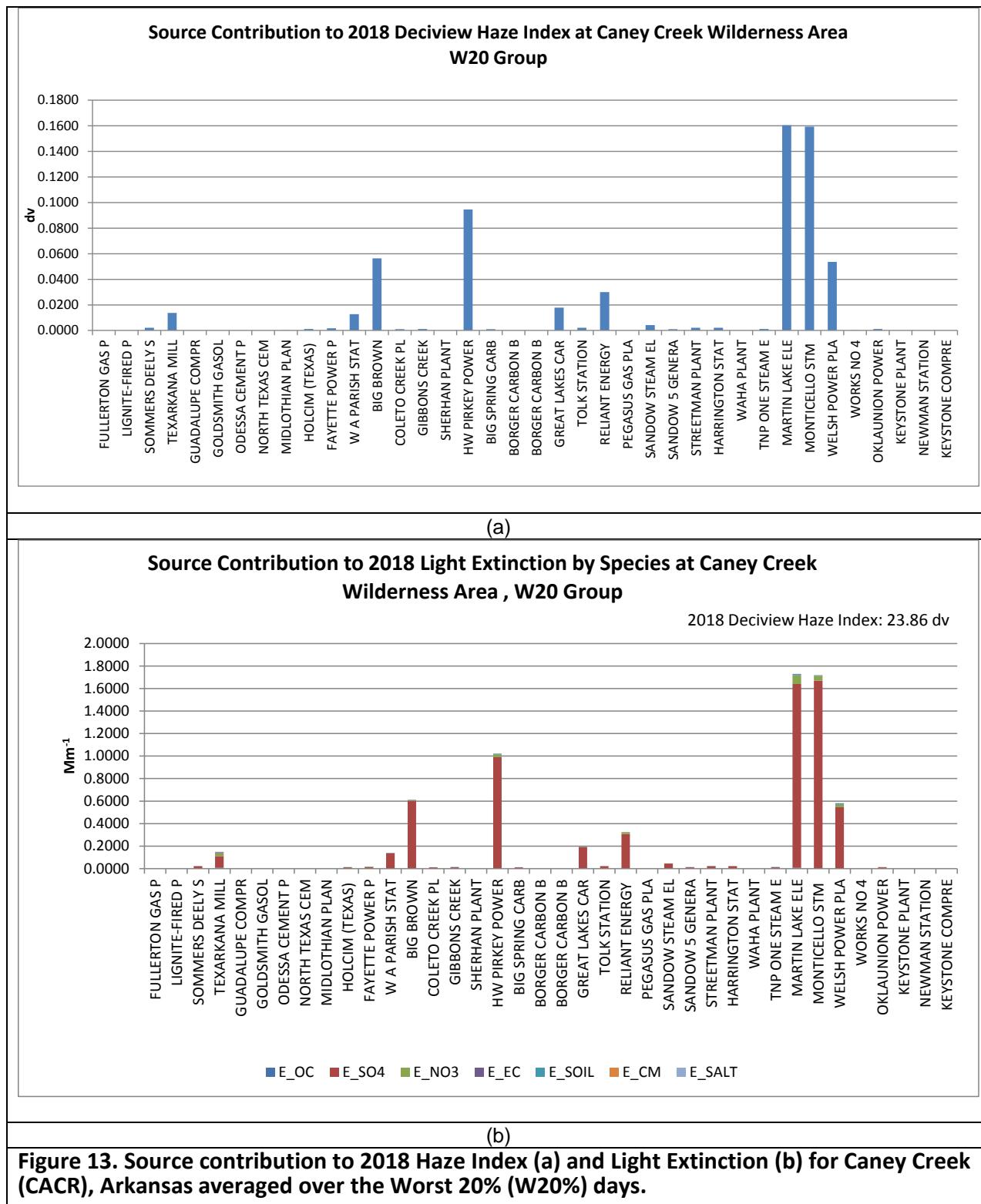


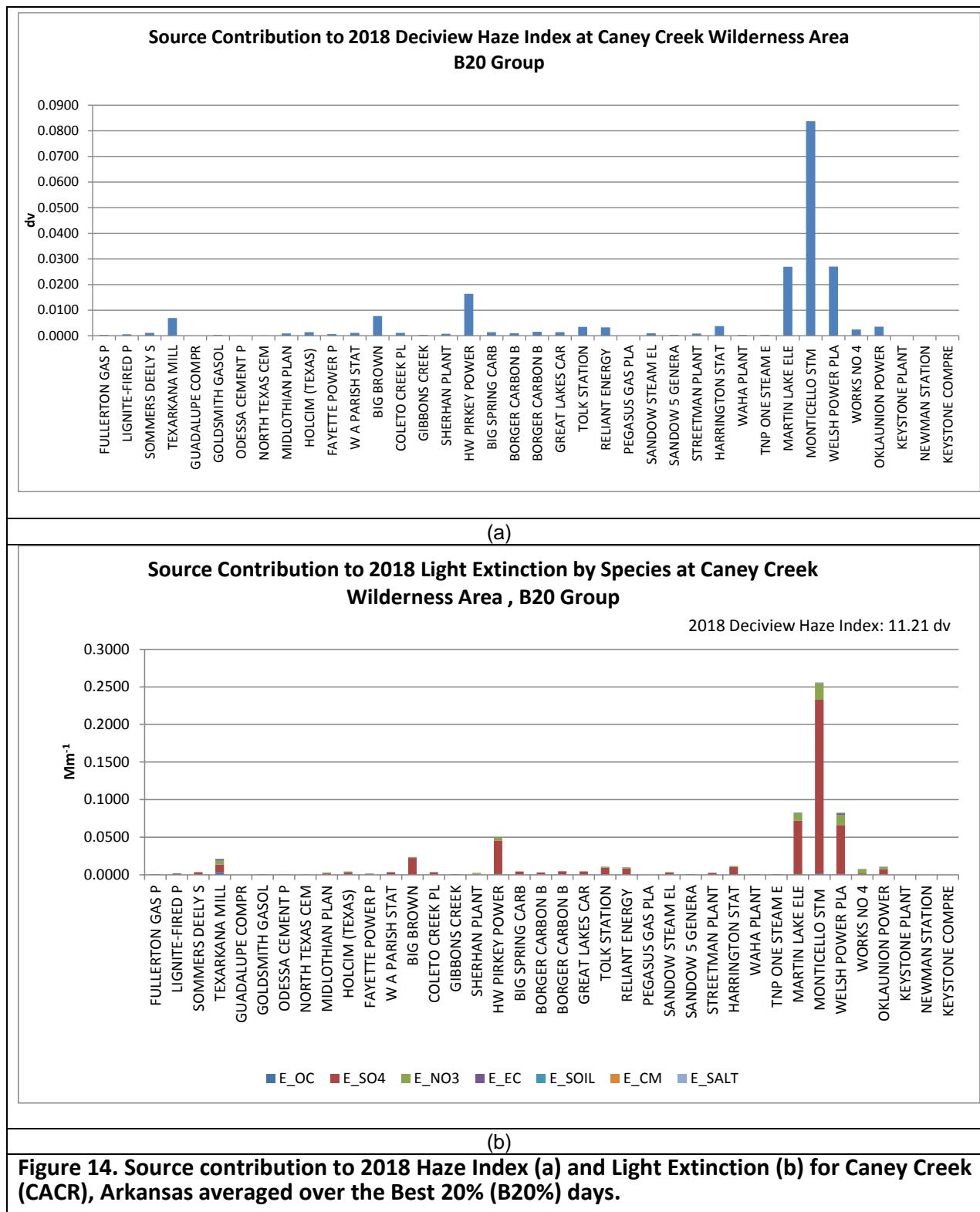












Uniform Rates of Progress and Projected 2018 Reasonable Progress Goals

In preparing a regional haze state implementation plan (SIP) each state must “analyze and determine the uniform rate of progress (glide path) needed to attain natural visibility conditions by the year 2064.” (40 Code of Federal Regulations (CFR) §51.308(d)(1)(i)(B)) Each state with one or more Class I areas must set a reasonable progress goal (measured in deciviews) for each of its Class I areas and compare the reasonable progress goal to the glide slope for the Class I area.

“The reasonable progress goals must provide for an improvement for the most impaired days [the worst 20 percent of monitored days] over the period of the implementation plan and ensure no degradation in visibility for the least impaired days [the best 20 percent of monitored days] over the same period.” (40 CFR §51.308(d)(1)) The period of the first regional haze SIP is from its adoption to 2018. The uniform rate of progress line is a straight line from the 2000 through 2004 base period impairment for the worst 20 percent of monitored days plotted from 2004 to natural conditions plotted for 2064.

The worst 20% days for 2064 natural conditions in this study are the same as the natural conditions used in the CENRAP Technical Support Document (ENVIRON and CERT, 2007). The baseline values (2000-2004) are calculated by the MATS software. A glide path for the W20% days is a straight line from the baseline to 2064 natural condition at each Class I area; whereas a glide path for the B20% days is a straight horizontal line from the baseline value to the natural condition. Figures 15-18 show glide paths at the four Class I areas. The green and red dots shown on each plot are 2018 projected visibility based on the CAMx model results.

The 2018 progress goals on the worst 20% days are not reached at all four Class I areas shown. Nonetheless, no degradation in visibility occurs on the best 20% days.

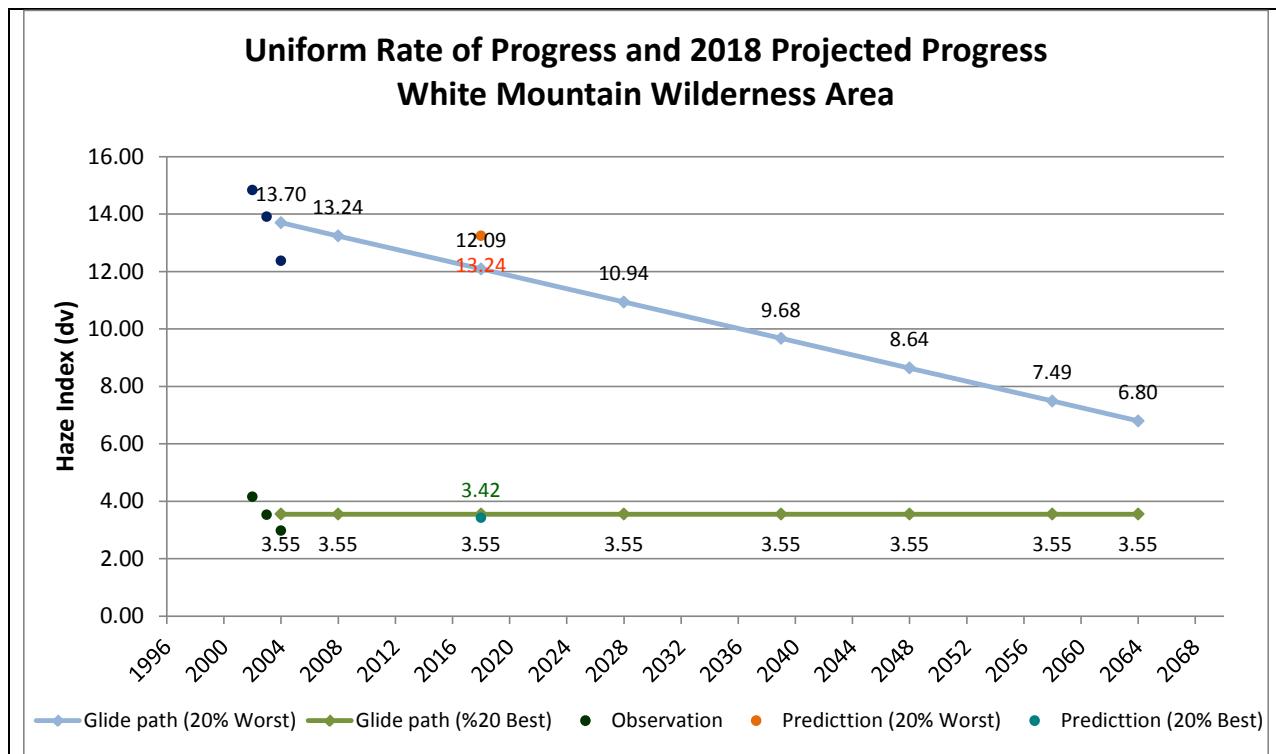


Figure 15. Uniform Rate of Progress and 2018 projected progress for White Mountain Wilderness Area (WIMO).

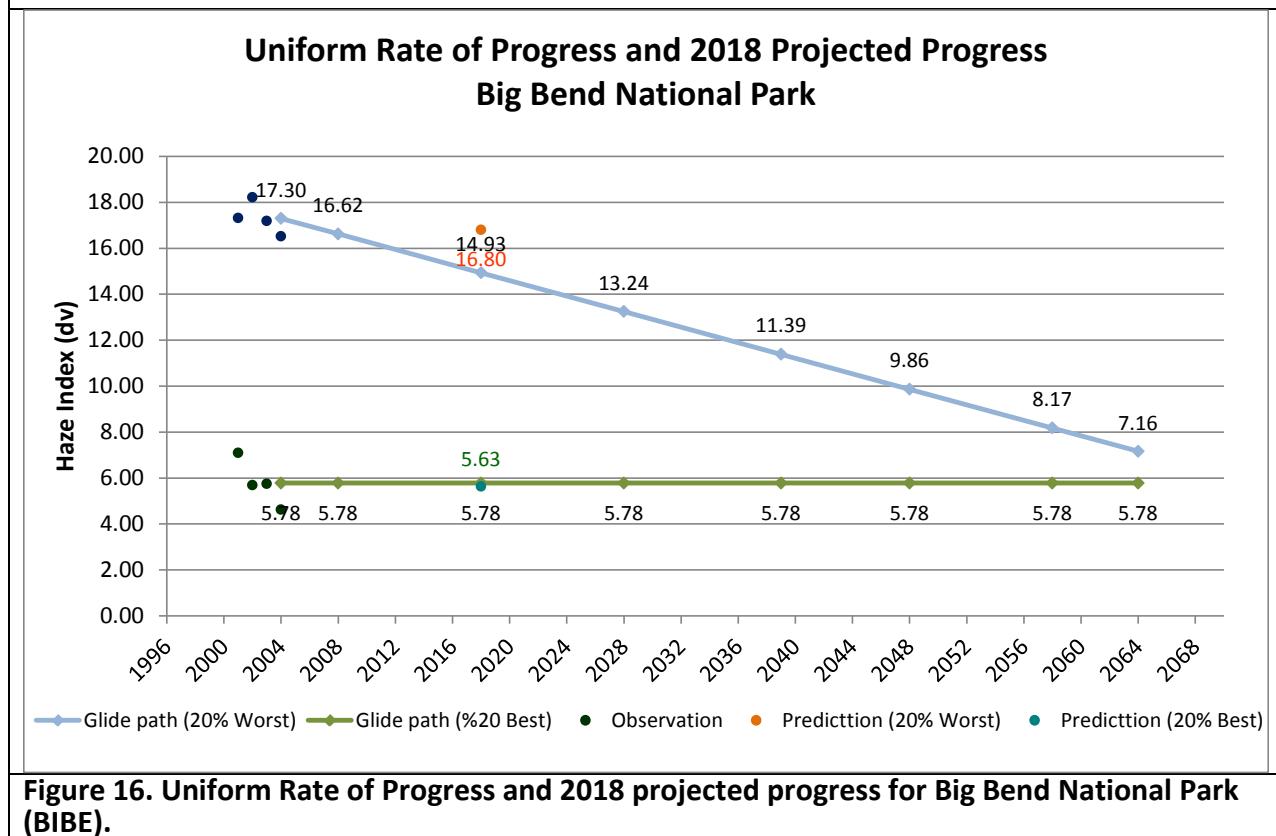


Figure 16. Uniform Rate of Progress and 2018 projected progress for Big Bend National Park (BIBE).

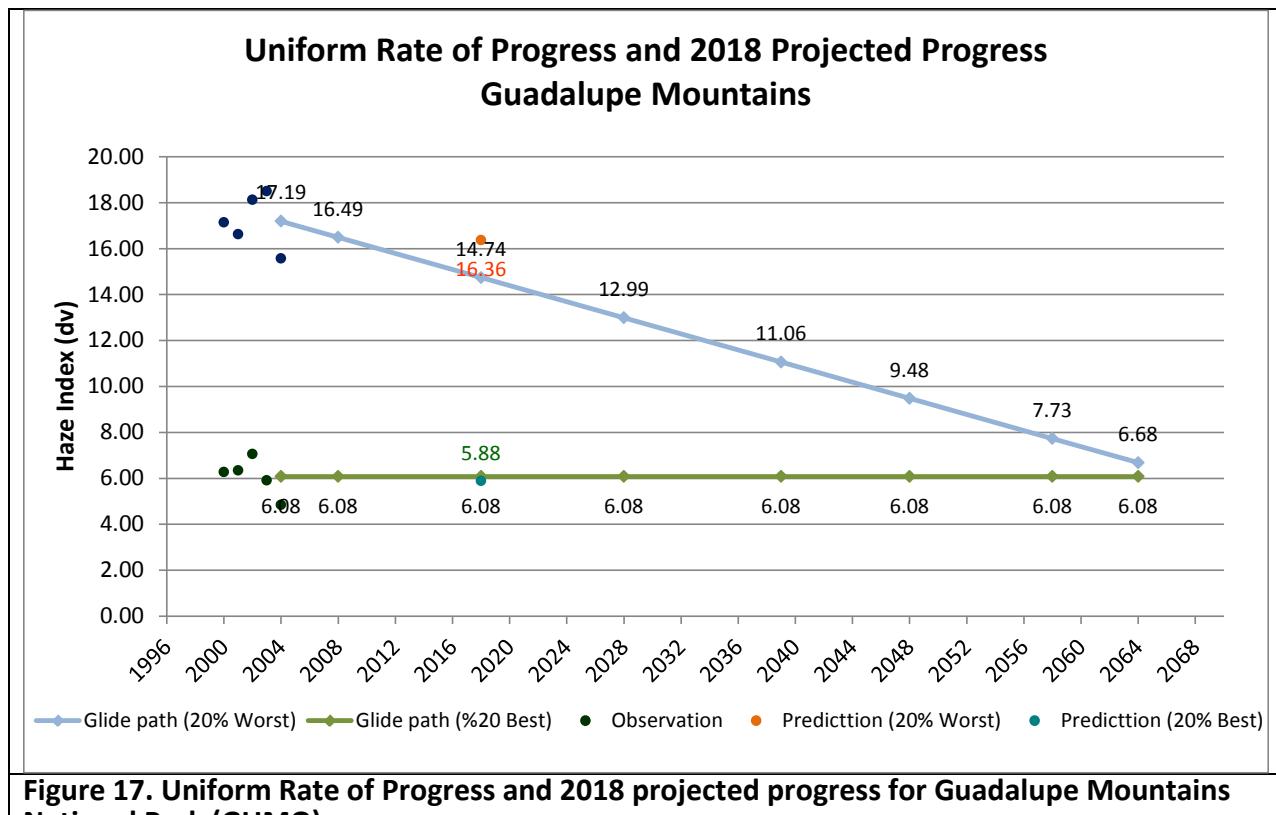


Figure 17. Uniform Rate of Progress and 2018 projected progress for Guadalupe Mountains National Park (GUMO).

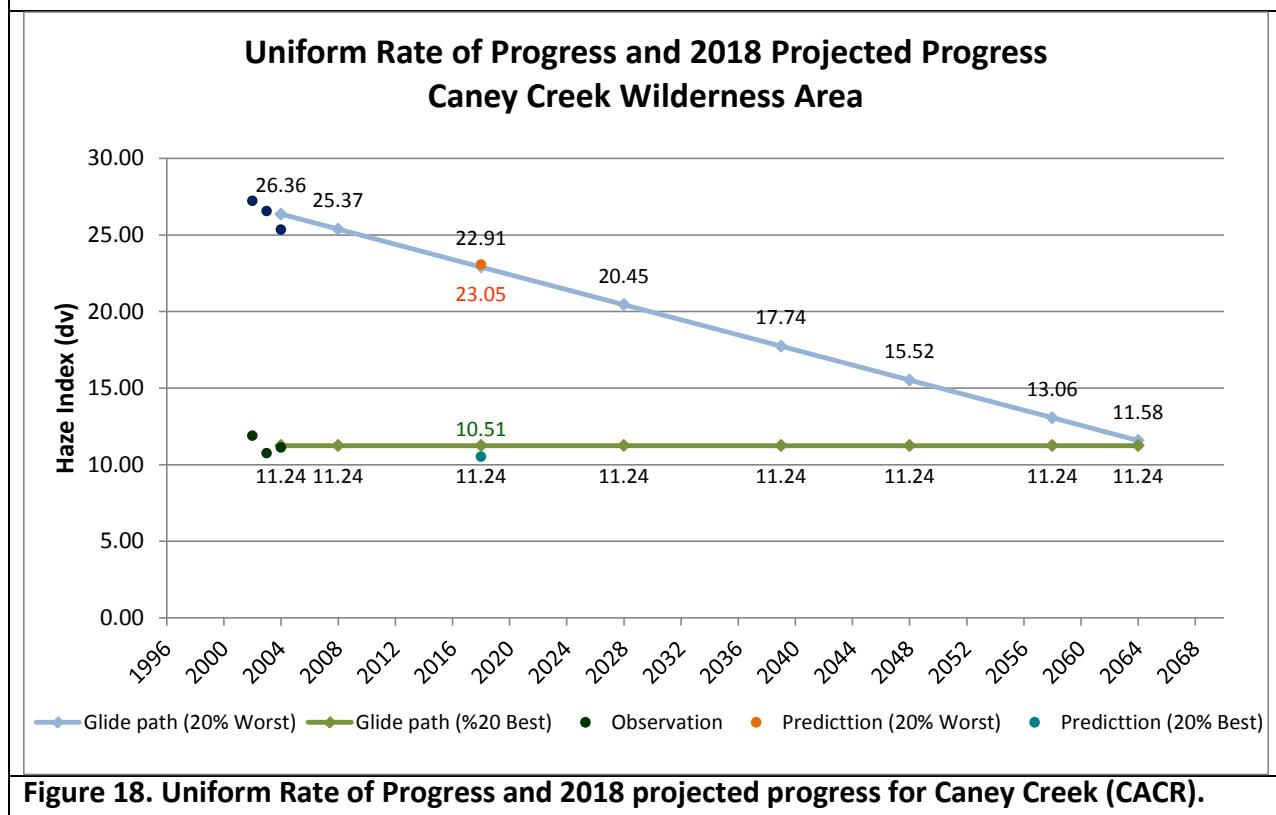


Figure 18. Uniform Rate of Progress and 2018 projected progress for Caney Creek (CACR).

SUMMARY

Air quality modeling results for the 2018 base case simulation are presented by pollutant of concern, including ozone and PM. Overall, the air quality maps show consistent spatial patterns between the 2002 and 2018 results with lower concentrations predicted in the 2018 base case. PM composition between the two simulations also is similar. The predicted 2018 ozone and PM concentrations are within reasonable ranges.

Sulfate appears to be the main constituent that contributes to visibility degradation at the Class I areas in/near Texas on both B20% and W20% cases. Proximity of target sources to Class I areas and magnitude of SO₂ emissions are factors that influence visibility impacts at these four Class I areas. The Excel Spreadsheets accompanying this memorandum can be a useful tool in identifying sources that contribute to modeled visibility degradation.,

The glide path analysis shows that the 2018 progress goals on the worst 20% days are not reached at all four Class I areas shown in this report (i.e., WIMO, CACR, BIBE and GUMO). Nonetheless, no degradation in visibility occurs on the best 20% days.

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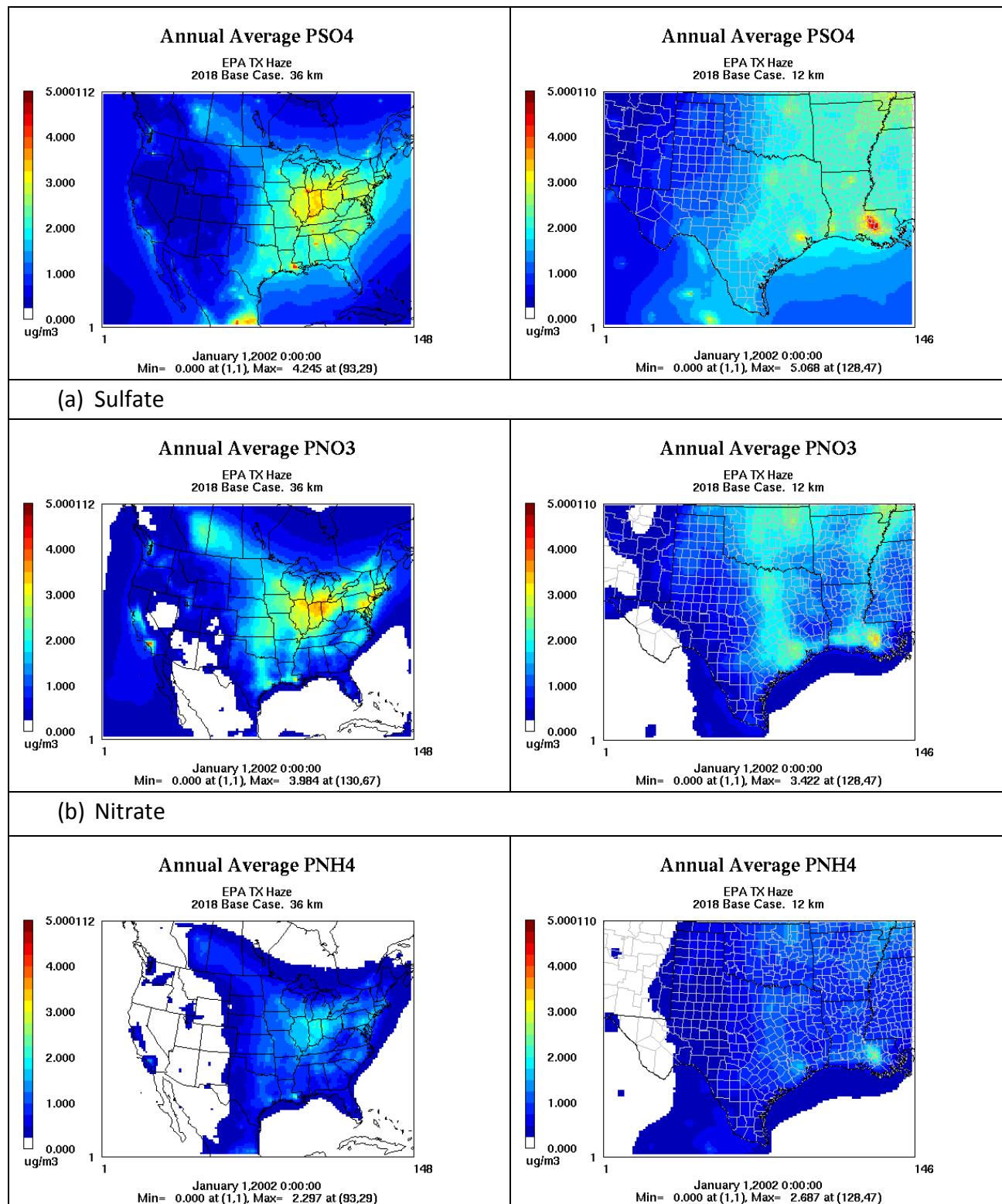
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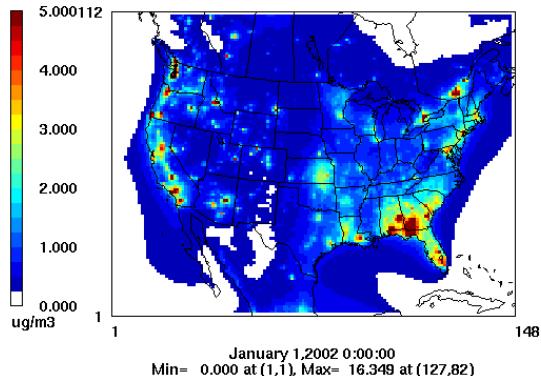
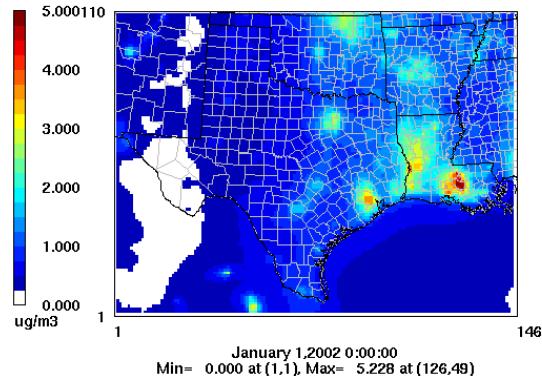
APPENDIX A

Annual Average PM Constituents from the CAMx 2018 Base Case results

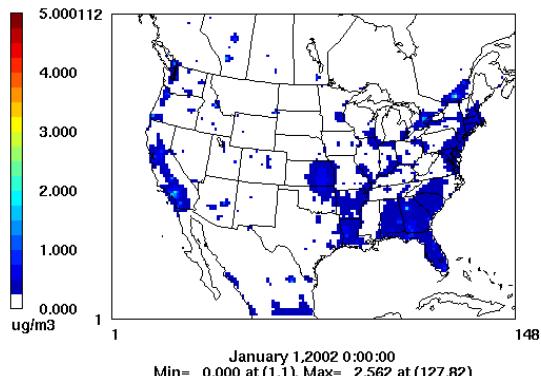
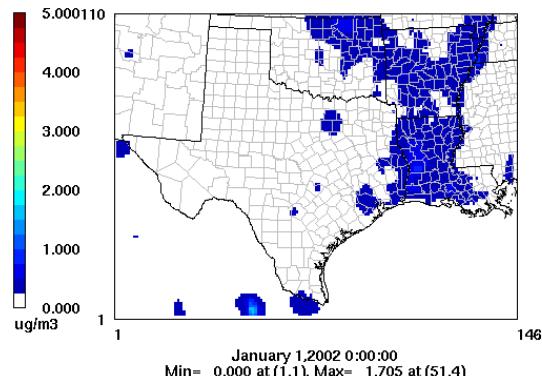
Appendix A: Annual Average PM Constituents from the CAMx 2018 Base Case results



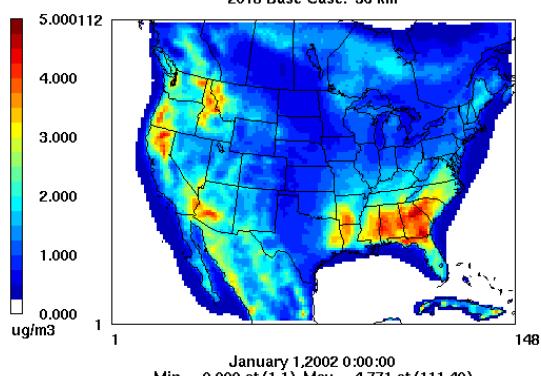
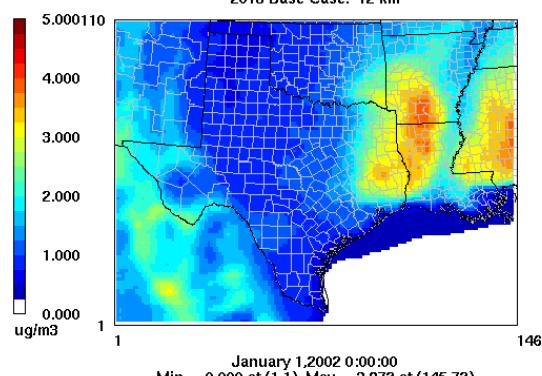
(c) Ammonium

Annual Average POAEPA TX Haze
2018 Base Case. 36 km**Annual Average POA**EPA TX Haze
2018 Base Case. 12 km

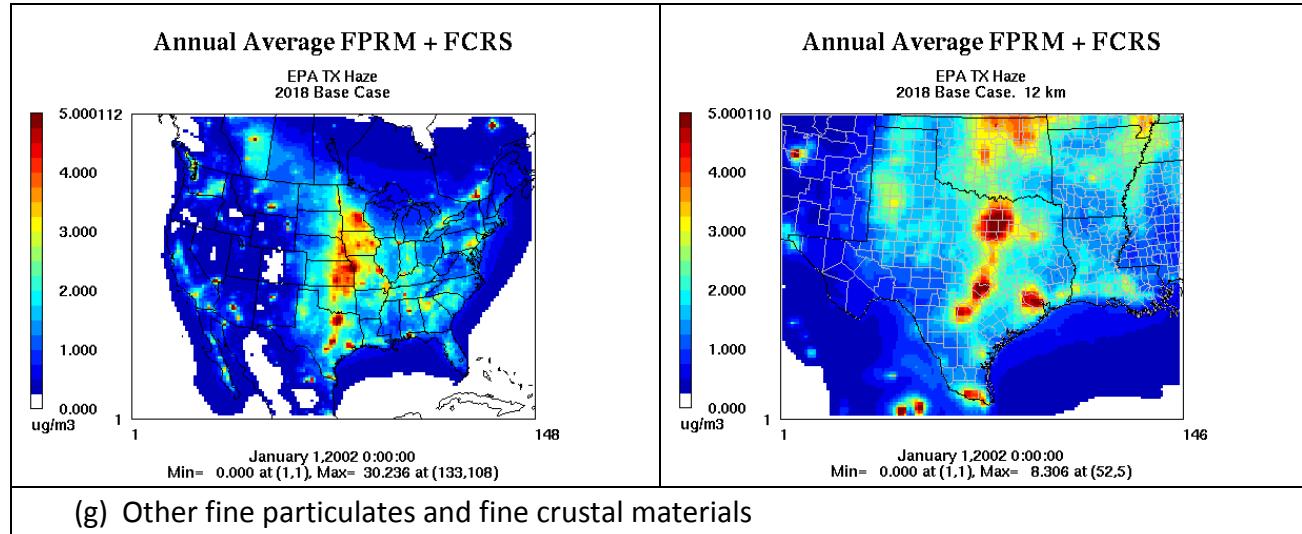
(d) Organic aerosols

Annual Average PECEPA TX Haze
2018 Base Case. 36 km**Annual Average PEC**EPA TX Haze
2018 Base Case. 12 km

(e) Elemental Carbon

Annual Average SOAEPA TX Haze
2018 Base Case. 36 km**Annual Average SOA**EPA TX Haze
2018 Base Case. 12 km

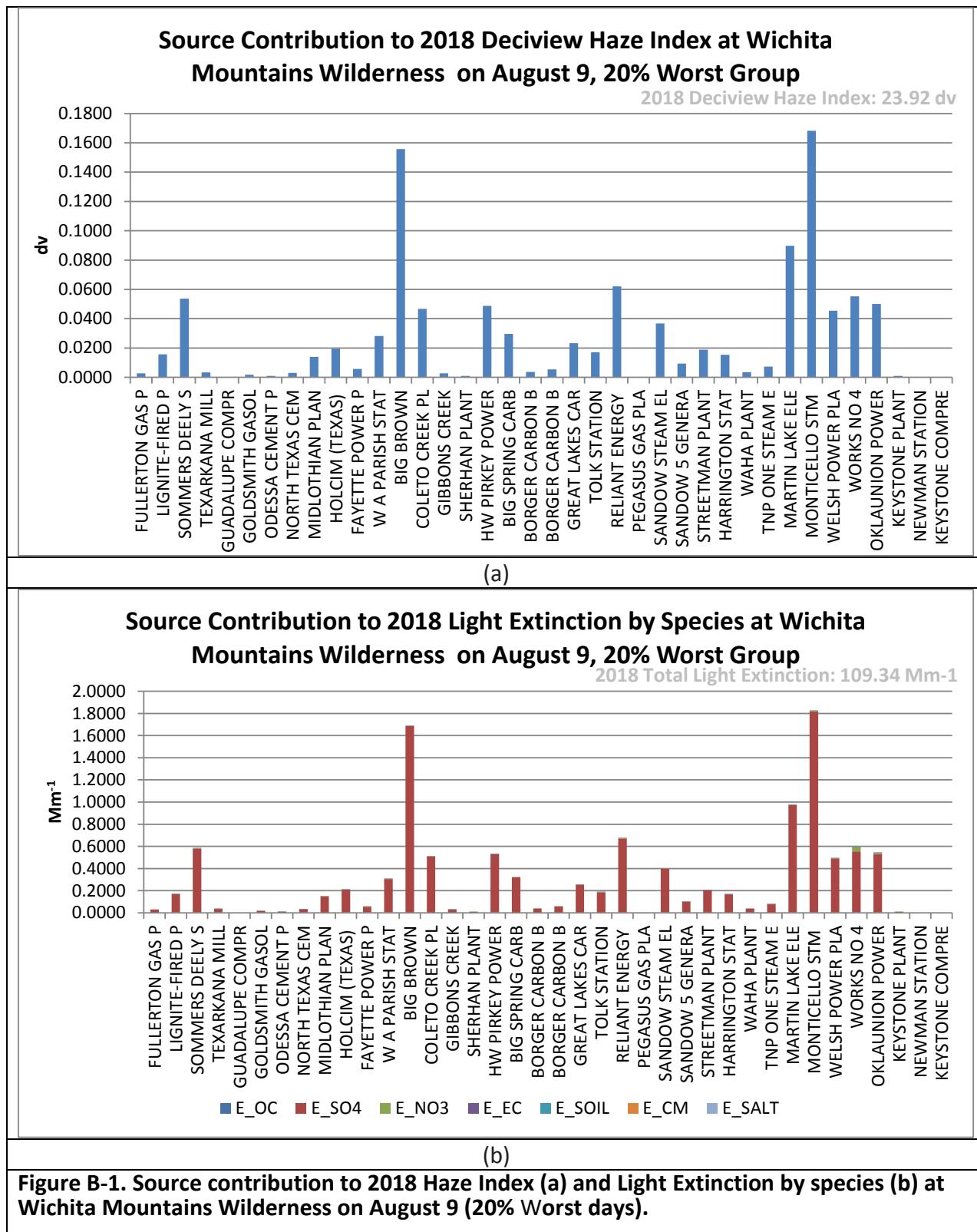
(f) Secondary organic aerosols





APPENDIX B
Visibility Analysis for 2018 Base Case Emission Scenario

Appendix B: Example of additional presentations showing contributions from target sources



Source Contribution to 2018 AMM_SO4 Light Extinction at Wichita Mountains Wilderness on August 9, 20% Worst Group

2018 AMM_SO4 Light Extinction: 60.0113 Mm⁻¹

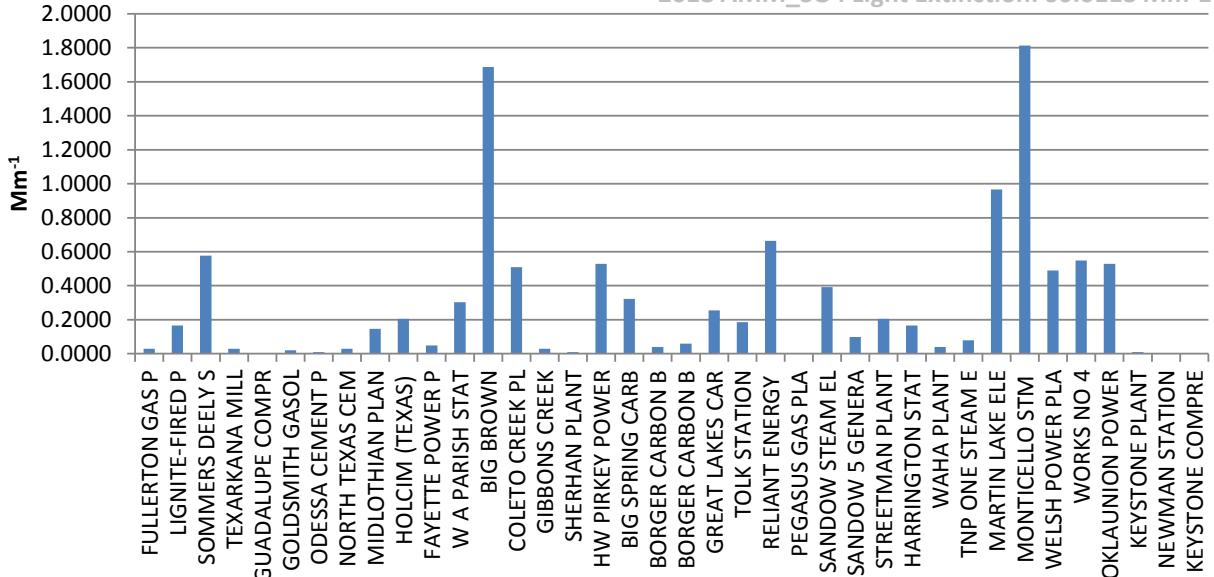


Figure B-2. Source Contribution to 2018 AMM_SO4 Light Extinction at Wichita Mountains Wilderness on August 9 (20% Worst days).

Percentage of Total Extinction at Wichita Mountains Wilderness on August 9, 20% Worst Group

2018 Deciview Haze Index: 23.92 dv

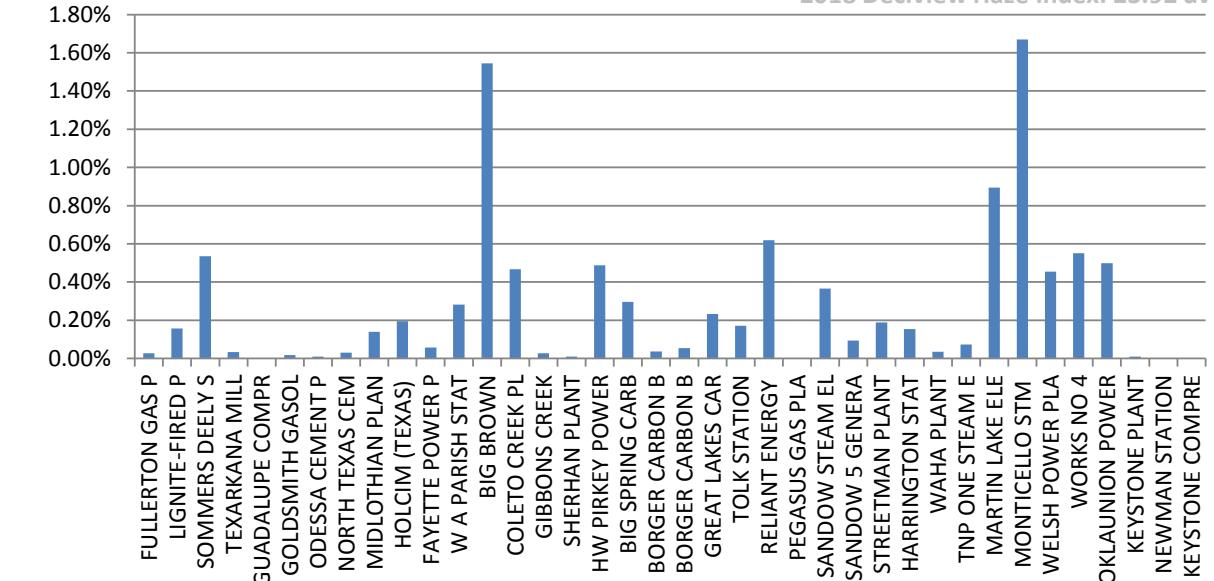


Figure B-3. Percentage of Total Extinction at Wichita Mountains Wilderness on August 9 (20% Worst days).

**Percentage of total SO₄ extinction at Wichita Mountains
Wilderness on August 9, 20% Worst Group**

2018 Deciview Haze Index: 23.92 dv

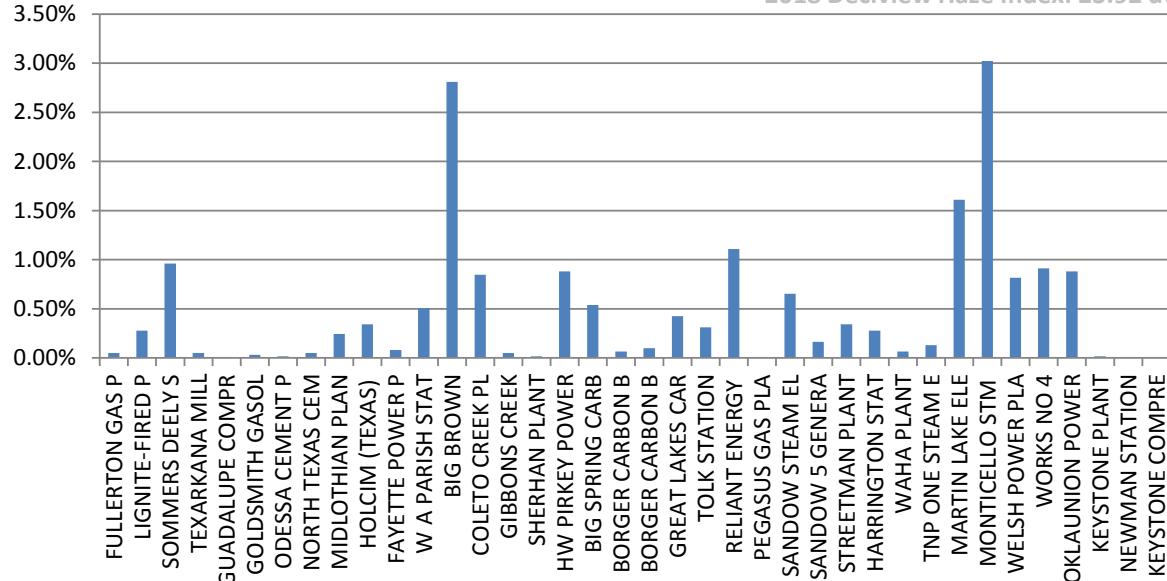


Figure B-4. Percentage of Total Sulfate Extinction at Wichita Mountains Wilderness on August 9 (20% Worst Days).

**Percentage of total NO₃ extinction at Wichita Mountains
Wilderness on August 9, 20% Worst Group**

2018 Deciview Haze Index: 23.92 dv

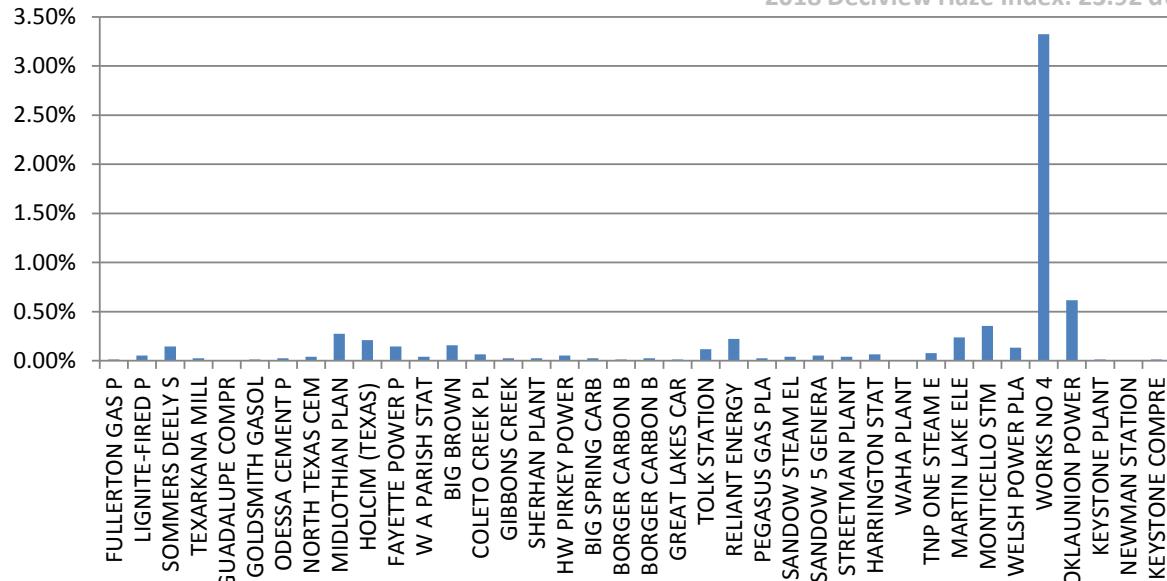
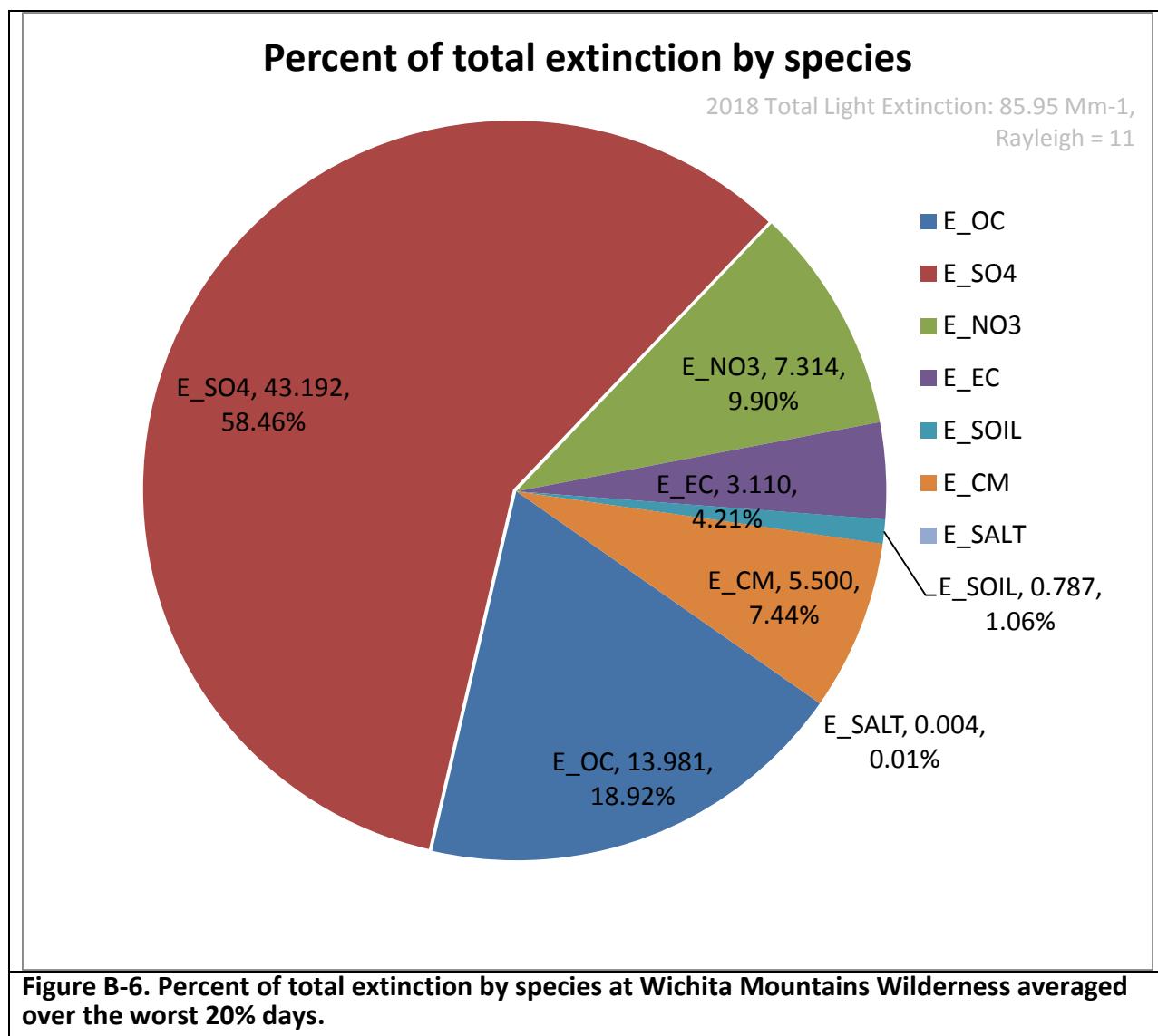


Figure B-5. Percentage of Total Nitrate Extinction at Wichita Mountains Wilderness on August 9 (20% Worst Days).



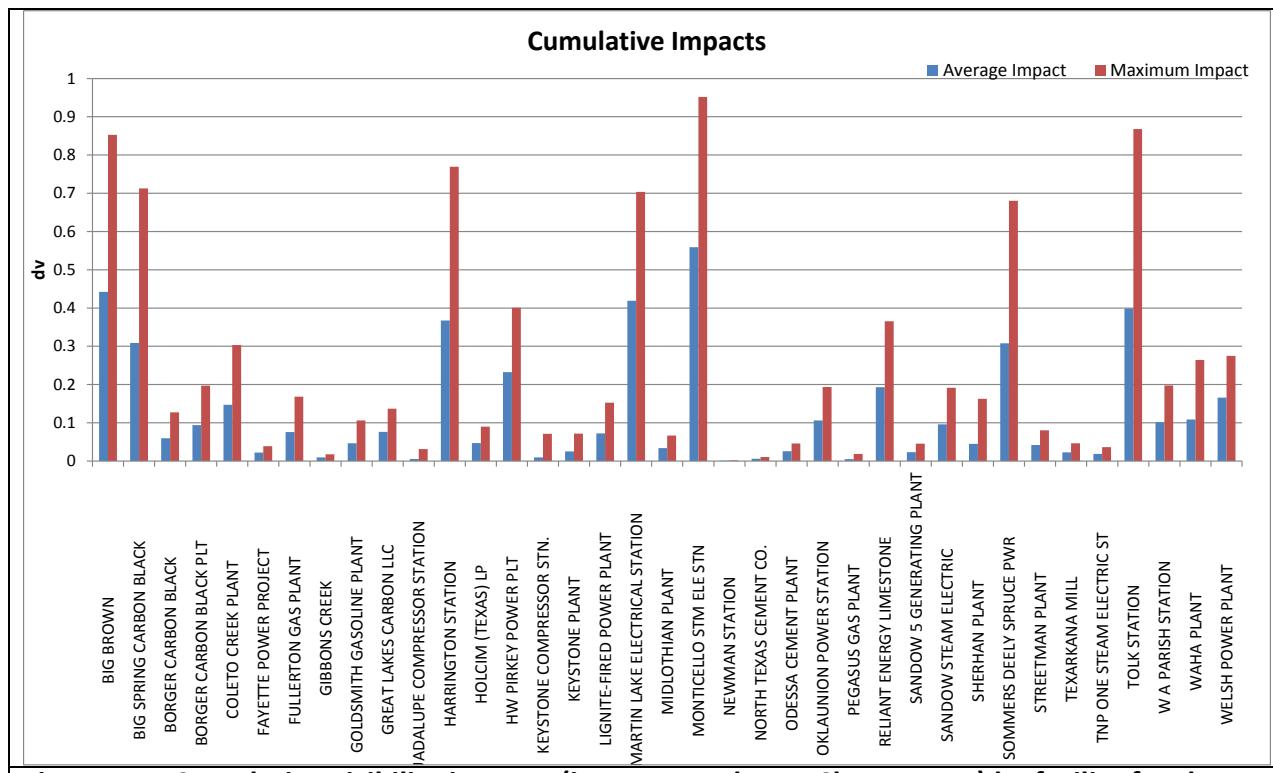


Figure B-7. Cumulative visibility impacts (i.e., summed over Class I areas) by facility for the worst 20% days.

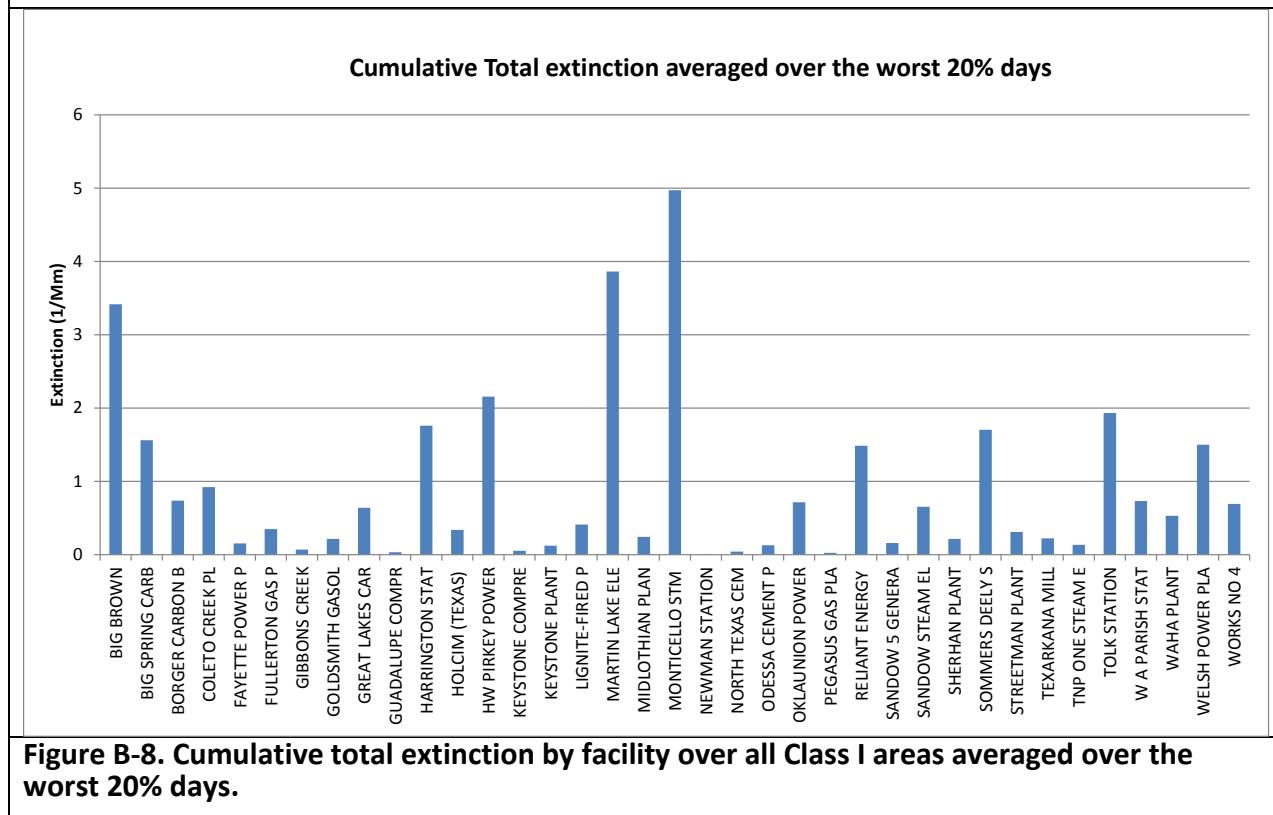


Figure B-8. Cumulative total extinction by facility over all Class I areas averaged over the worst 20% days.